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THE NASTRAN® USER'S MANUAL

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INTRODUCTION

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The User's Manual is one of four manuals that constitute the documentation for NASTRAN, the other three being the Theoretical Manual, the Programmer's Manual and the Demonstration Problem Manual. Although the User's Manual contains all of the information that is directly associated with the solution of problems with NASTRAN, the user will find it desirable to refer to the other manuals for assistance in the solution of specific user problems.

The Theoretical Manual gives an excellent introduction to NASTRAN and presents developments of the analytical and numerical procedures that underlie the program. The User's Manual is instructive and encyclopedic in nature, but is restricted to those items related to the use of NASTRAN that are generally independent of the computing system being used. Computer-dependent topics and information that is required for the maintenance and modification of the program are treated in the Programmer's Manual. The Programmer's Manual also provides a complete description of the program including the mathematical equations implemented in the code. The Demonstration Problem Manual presents a discussion of the sample problems delivered with NASTRAN, thereby illustrating the formulation of the different types of problems that can be solved with NASTRAN.

In addition to the four manuals described above, there is also a NASTRAN User's Guide that serves as a handbook for users. It describes all of the NASTRAN features and options and illustrates them by examples. Other excellent sources for NASTRAN-related topics are the proceedings of the NASTRAN Users' Colloquia (held normally every year) which provide a large body of information based on user experiences with NASTRAN.

NASTRAN uses the finite element approach to structural modeling, wherein the distributed physical properties of a structure are represented by a finite number of structural elements which are interconnected at a finite number of grid points, to which loads are applied and for which displacements are calculated. The procedures for defining and loading a structural model are described in Section 1. This section contains a functional reference for every card that is used for structural modeling.

The NASTRAN Data Deck, including the details for each of the data cards, is described in Section 2. This section also discusses the NASTRAN control cards that are associated with the use of the program.

NASTRAN contains problem solution sequences, called rigid formats. Each of these rigid formats is associated with the solution of problems for a particular type of static or dynamic analysis. Section 3 contains a general description of rigid format procedures, along with specific instructions for the use of each rigid format.

The procedures for using the NASTRAN plotting capability are described in Section 4. Both deformed and undeformed plots of the structural model are available. Response curves are also available for static, transient response, frequency response, modal flutter and modal aeroelastic response analyses.

In addition to the rigid format procedures, the user may choose to write his own Direct Matrix Abstraction Program (DMAP). This procedure permits the user to execute a series of matrix operations of his choice along with any utility modules or executive operations that he may need. The rules governing the creation of DMAP programs are described in Section 5.

The NASTRAN diagnostic messages are documented and explained in Section 6. The NASTRAN Dictionary, in Section 7, contains descriptions of mnemonics, acronyms, phrases, and other commonly used NASTRAN terms.

There is a limited number of sample problems included in the User's Manual. However, a more comprehensive set of demonstration problems, at least one for each of the rigid formats, is described in the NASTRAN Demonstration Problem Manual. The data decks are available on tape, in the form of a User's Master File, for each of the computers on which NASTRAN has been implemented. Samples of the printer output and of structure plots and response plots can be obtained by executing these demonstration problems. The printer output for these problems is also available on microfiche.

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1. STRUCTURAL MODELING

1.1 INTRODUCTION

NASTRAN embodies a lumped element approach, wherein the distributed physical properties of a structure are represented by a model consisting of a finite number of idealized substructures or elements that are interconnected at a finite number of grid points, to which loads are applied. All input and output data pertain to the idealized structural model. The major components in the definition and loading of a structural model are indicated in Figure 1.

As indicated in Figure 1, the grid point definition forms the basic framework for the structural model. All other parts of the structural model are referenced either directly or indirectly to the grid points.

Two general types of grid points are used in defining the structural model. They are:

1. Geometric grid point - a point in three-dimensional space at which three components of translation and three components of rotation are defined. The coordinates of each grid point are specified by the user.

2. Scalar point - a point in vector space at which one degree of freedom is defined. Scalar points can be coupled to geometric grid points by means of scalar elements and by constraint relationships.

The structural element is a convenient means for specifying many of the properties of the structure, including material properties, mass distribution and some types of applied loads. In static analysis by the displacement method, stiffness properties are input exclusively by means of structural elements. Mass properties (used in the generation of gravity and inertia loads) are input either as properties of structural elements or as properties of grid points. In dynamic analysis, mass, damping, and stiffness properties may be input either as the properties of structural elements or as the properties of grid points (direct input matrices).

Structural elements are defined on connection cards by referencing grid points, as indicated on Figure 1. In a few cases, all of the information required to generate the structural matrices for the element is given on the connection card. In most cases the connection card refers to a property card, on which the cross-sectional properties of the element are given. The property card in turn refers to a material card which gives the material properties. If some of the material properties are stress dependent or temperature dependent, a further reference is made to tables for this information.

Various kinds of constraints can be applied to the grid points. Single-point constraints are used to specify boundary conditions, including enforced displacements of grid points.

Multipoint constraints and rigid elements are used to specify linear relationships among selected degrees of freedom. Omitted points are used as a tool in matrix partitioning and for reducing the number of degrees of freedom used in dynamic analysis. Free-body supports are used to remove stress-free motions in static analysis and to evaluate the free-body inertia properties of the structural model.

Static loads may be applied to the structural model by concentrated loads at grid points, pressure loads on surfaces, or indirectly, by means of the mass and thermal expansion properties of structural elements are enforced deformations of one-dimensional structural elements. Due to the great variety of possible sources for dynamic loading, only general forms of loads are provided to the user in dynamic analysis.

The following sections describe the general procedures for defining structural models. Detailed instructions for each of the bulk data cards and case control cards are given in Section 2. Additional information on the case control cards and use of parameters is given for each rigid format in Section 3.

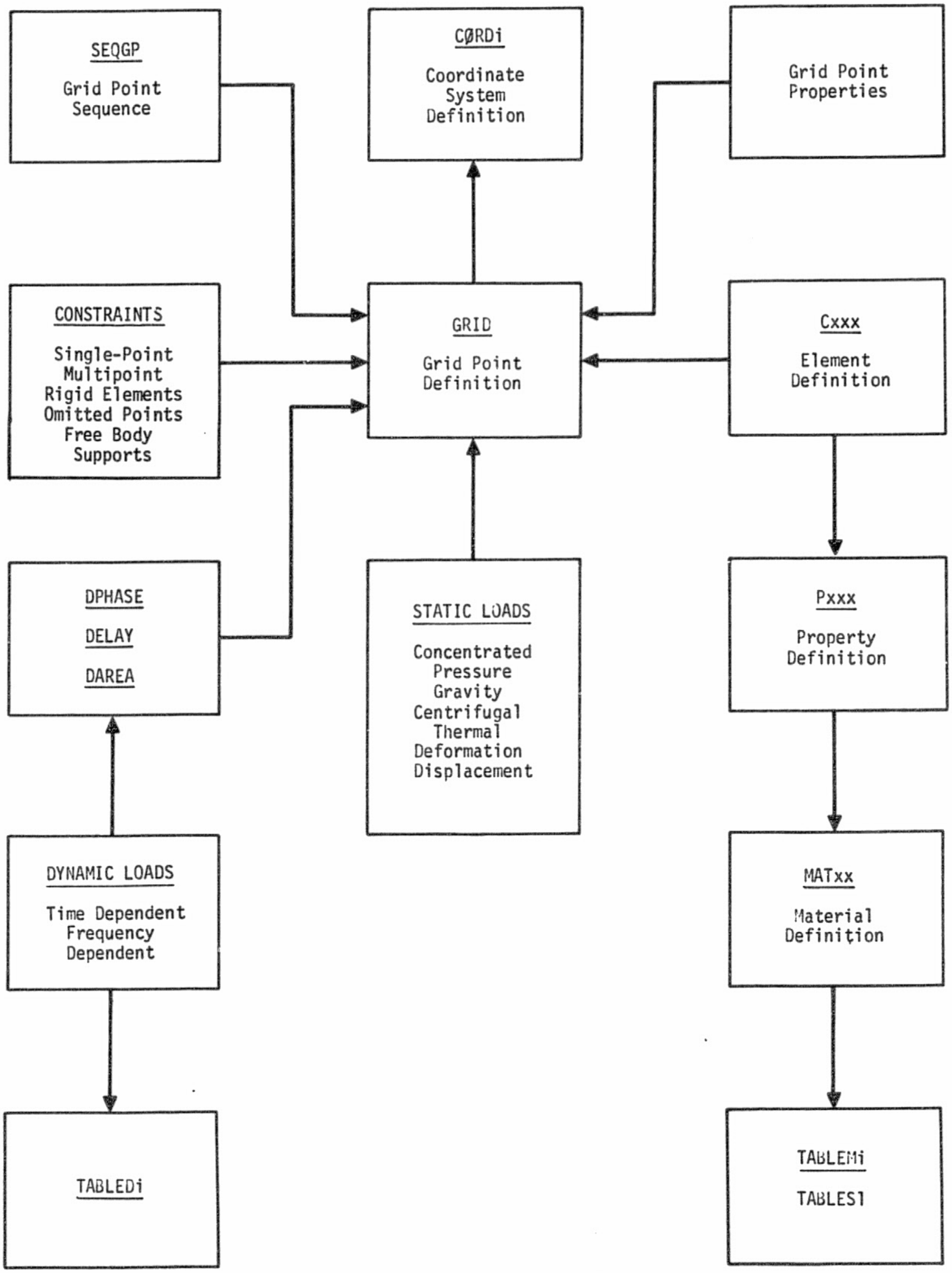

Figure 1. Structural model.

1.2 GRID POINTS

1.2.1 Grid Point Definition

Geometric grid points are defined on GRID bulk data cards by specifying their coordinates in either the basic or a local coordinate system. The implicitly defined basic coordinate system is rectangular, except when using axisymmetric elements. Local coordinate systems may be rectangular, cylindrical, or spherical. Each local system must be related directly or indirectly to the basic coordinate system. The CØRD1C, CØRD1R and CØRD1S cards are used to define cylindrical, rectangular and spherical local coordinate systems, respectively, in terms of three geometric grid points which have been previously defined. The CØRD2C, CØRD2R and CØRD2S cards are used to define cylindrical, rectangular and spherical local coordinate systems, respectively, in terms of the coordinates of three points in a previously defined coordinate system.

Six rectangular displacement components (3 translations and 3 rotations) are defined at each grid point. The local coordinate system used to define the directions of motion may be different from the local coordinate system used to locate the grid point. Both the location coordinate system and the displacement coordinate system are specified on the GRID card for each geometric grid point. The orientation of displacement components depends on the type of local coordinate system used to define the displacement components. If the defining local system is rectangular, the displacement system is parallel to the local system and is independent of the grid point location as indicated in Figure 1a. If the local system is cylindrical, the displacement components are in the radial, tangential and axial directions as indicated in Figure 1b. If the local system is spherical, the displacement components are in the radial, meridional, and azimuthal directions as indicated in Figure 1c. Each geometric grid point may have a unique displacement coordinate system associated with it. The collection of all displacement coordinate systems is known as the global coordinate system. All matrices are formed and all displacements are output in the global coordinate system. The symbols T1, T2 and T3 on the printed output indicate translations in the 1, 2 and 3-directions, respectively, for each grid point. The symbols R1, R2 and R3 indicate rotations (in radians) about the three axes.

Provision is also made on the GRID card to apply single-point constraints to any of the displacement components. Any constraints specified on the GRID card will be automatically used for all solutions. Constraints specified on the GRID card are usually restricted to those degrees of

freedom that will not be elastically constrained and hence must be removed from the model in order to avoid singularities in the stiffness matrix.

The GRDSET card is provided to avoid the necessity of repeating the specification of location coordinate systems, displacement coordinate systems, and single-point constraints, when all, or many, of the GRID cards have the same entries for these items. When any of the three items are specified on the GRDSET card, the entries are used to replace blank fields on the GRID card for these items. This feature is useful in the case of such problems as space trusses where one wishes to remove all of the rotational degrees of freedom or in the case of plane structures where one wishes to remove all of the out-of-plane or all of the in-plane motions.

Scalar points are defined either on an SPØINT card or by reference on a connection card for a scalar element. SPØINT cards are used primarily to define scalar points appearing in constraint equations, but to which no structural elements are connected. A scalar point is implicitly defined if it is used as a connection point for any scalar element. Special scalar points, called "extra points", may be introduced for dynamic analyses. Extra points are used in connection with transfer functions and other forms of direct matrix input used in dynamic analyses and are defined on EPØINT cards.

GRIDB is a variation of the GRID card that is used to define a point on a fluid-structure interface (see Section 1.7).

1.2.2 Grid Point Sequencing

The external identification numbers used for grid points may be selected in any manner the user desires. However, in order to reduce the number of active columns, and, hence, to substantially reduce computing times when using the displacement method, the internal sequencing of the grid points must not be arbitrary. The best decomposition and equation solution times are obtained if the grid points are sequenced in such a manner as to create matrices having small numbers of active columns (see Section 2.2 of the Theoretical Manual for a discussion of active columns and the decomposition algorithm). The decomposition time is proportional to the sum of the squares of the number of active columns in each row of the triangular factor. The equation solution time (forward/backward substitution) is proportional to the number of nonzero terms in the triangular factor.

1.2.2.1 Manual Grid Point Resequencing

In order to allow arbitrary grid point numbers and still preserve sparsity in the triangular decomposition factor to the greatest extent possible, provision is made for the user to resequence the grid point numbers for internal operations. This feature also makes it possible to easily change the sequence if a poor initial choice is made. All output associated with grid points is identified with the external grid point numbers. The SEQGP card is used to resequence geometric grid points and scalar points. The SEQEP card is used to sequence the extra points in with the previously sequenced grid points and scalar points.

In selecting the grid point sequencing, it is not important to find the best sequence, rather it is usually quite satisfactory to find a good sequence, and to avoid bad sequences that create unreasonably large numbers of active columns. For many problems a sequence which will result in a band matrix is a reasonably good choice, but not necessarily the best. Also, sequences which result in small numbers of columns with nonzero terms are usually good but not necessarily the best. A sequence with a larger number of nonzero columns will frequently have a smaller number of nonzero operations in the decomposition when significant passive regions exist within the active columns (see Section 2.2 of the Theoretical Manual).

Examples of proper grid point sequencing for one-dimensional systems are shown in Figure 2. For open loops, a consecutive numbering system should be used as shown in Figure 2a. This sequencing will result in a narrow band matrix with no new nonzero terms created during the triangular decomposition. Generally, there is an improvement in the accumulated round off error if the grid points are sequenced from the flexible end to the stiff end.

For closed loops, the grid points may be sequenced either as shown in Figure 2b or as shown in Figure 2c. If the sequencing is as shown in Figure 2b, the semiband will be twice that of the model shown in Figure 2a. The matrix will initially contain a number of zeroes within the band which will become nonzero as the decomposition proceeds. If the sequencing is as shown in Figure 2c, the band portion of the matrix will be the same as that for Figure 2a. However, the connection between grid points 1 and 8 will create a number of active columns on the right hand side of the matrix. The solution times will be the same for the sequence shown in Figure 2b or 2c, because the number of active columns in each sequence is the same.

Examples of grid point sequencing for surfaces are shown in Figure 3. For plain or curved surfaces with a pattern of grid points that tends to be rectangular, the sequencing shown in Figure 3a will result in a band matrix having good solution times. The semiband will be proportional to

the number of grid points along the short direction of the pattern. If the pattern of grid points shown in Figure 3a is made into a closed surface by connecting grid points 1 and 17, 2 and 18, etc., a number of active columns equal to the semiband will be created. If the number of grid points in the circumferential direction is greater than twice the number in the axial direction, the sequencing indicated in Figure 3a is a good one. However, if the number of grid points in the circumferential direction is less than twice the number in the axial direction, the use of consecutive numbering in the circumferential direction is more efficient. An alternate sequencing for a closed loop is shown in Figure 3b, where the semiband is proportional to twice the number of grid points in a row. For cylindrical or similar closed surfaces, the sequencing shown in Figure 3b has no advantage over that shown in Figure 3a, as the total number of active columns will be the same in either case.

With the exception of the central point, sequencing considerations for the radial pattern shown in Figure 3c are similar to those for the rectangular patterns shown in Figures 3a and 3b. The central point must be sequenced last in order to limit the number of active columns associated with this point to the number of degrees of freedom at the central point. If the central point is sequenced first, the number of active columns associated with the central point will be proportional to the number of radial lines. If there are more grid points on a radial line than on a circumferential line, the consecutive numbering should extend in the circumferential direction beginning with the outermost circumferential ring. In this case, the semiband is proportional to the number of grid points on a circumferential line and there will be no active columns on the right hand side of the matrix. If the grid points form a full circular pattern, the closure will create a number of active columns proportional to the number of grid points on a radial line if the grid points are numbered as shown in Figure 3c. Proper sequencing for a full circular pattern is similar to that discussed for the rectangular arrays shown in Figures 3a and 3b for closed surfaces.

Sequencing problems for actual structural models can frequently be handled by considering the model as consisting of several substructures. Each substructure is first numbered in the most efficient manner. The substructures are then connected so as to create the minimum number of active columns. The grid points at the interface between two substructures are usually given numbers near the end of the sequence for the first substructure and as near the beginning of the sequence for the second substructure as is convenient.

Figure 4 shows a good sequence for the substructure approach. Grid points 1 thru 9 are associated with the first substructure, and grid points 10 thru 30 are associated with the second substructure. In the example, each of the substructures was sequenced for band matrices. However, other schemes could also be considered for sequencing the individual substructures. Figure 5 shows the nonzero terms in the triangular factor. The X's indicate terms which are nonzero in the original matrix. The zeros indicate nonzero terms created during the decomposition. The maximum number of active columns for any pivotal row is only five, and this occurs in only three rows near the middle of the matrix for the second substructure. All other pivotal rows have four or less active columns.

Figure 6 indicates the grid point sequencing using substructuring techniques for a square model, and Figure 7 shows the nonzero terms in the triangular factor. If the square model were sequenced for a band matrix, the number of nonzero terms in the triangular factor would be 129, whereas Figure 7 contains only 102 nonzero terms. The time for the forward/backward substitution operation is directly proportional to the number of nonzero terms in the triangular factor. Consequently, the time for the forward/backward substitution operation when the square array is ordered as shown in Figure 7 is only about 80% of that when the array is ordered for a band matrix. The number of multiplications for a decomposition when ordered for a band is 294, whereas the number indicated in Figure 7 is only 177. This indicates that the time for the decomposition when ordered as shown in Figure 6 is only 60% of that when ordered for a band.

Although scalar points are defined only in vector space, the pattern of the connections is used in a manner similar to that of geometric grid points for sequencing scalar points among themselves or with geometric grid points. Since scalar points introduced for dynamic analysis (extra points) are defined in connection with direct input matrices, the sequencing of these points is determined by direct reference to the positions of the added terms in the dynamic matrices.

1.2.2.2 Automatic Grid Point Resequencing Using the BANDIT Procedure

A user desiring reduced matrix reduction and equation solution times can manually resequence his grid points by the use of SEQGP cards as per the guidelines outlined in the previous section. However, in order to relieve the user of the burden of having to do so, an automatic resequencing capability has been provided in NASTRAN. This capability involves the use of the BANDIT procedure in NASTRAN. (See Reference 1 for details of the BANDIT procedure and Reference 2 for details of the manner in which it has been implemented in NASTRAN.)

The BANDIT procedure in automatically invoked in NASTRAN for all runs (except those indicated in Sections 1.2.2.2.2 and 1.2.2.2.3), unless specifically suppressed by the user. (See the description of the BANDIT options in the next section.) The result of the BANDIT operations is a set of SEQGP cards that are automatically generated by the program. These SEQGP cards are added to the user-supplied input data (replacing any SEQGP cards already input, if so specified) for subsequent processing by the program.

1.2.2.2.1 BANDIT Options

The execution of the BANDIT operations in NASTRAN is controlled by several parameters. These paramaters can be specified by means of the NASTRAN card and are fully described in Section 2.1. All of these parameters have default values selected so that a user normally does not have to explicitly specify any of them.

Currently NASTRAN provides two methods to skip over the BANDIT operations. First, the NASTRAN BANDIT=-1 option can be used. The second method is to include one or more SEQGP cards in the Bulk Data Deck. In this second method, BANDIT would terminate since the user has already stated his choice of SEQGP resequencing cards. However, the NASTRAN BANDTRUN=1 option can be used to force BANDIT to generate new SEQGP cards to replace the old SEQGP set already in the input Bulk Data Deck. In all instances when BANDIT is executed, NASTRAN will issue a page of summary to keep the user informed of the basic resequencing computations. The user may refer to Reference 1 for the definition of the technical terms used.

The BANDIT procedure automatically counts the number of grid points used in a NASTRAN job and sets up the exact array dimensions needed for its internal computations. However, if the user's structural model uses more grid points in the connecting elements than the total number of grid points as defined on the GRID cards, BANDIT will issue a fatal message and terminate the job. In the case where non-active grid points (that is, grid points defined on the GRID cards but nowhere used in the model) do exist, BANDIT will add them to the end of the SEQGP cards, and their presence will not cause termination of a job. (If necessary, the NASTRAN HICØRE parameter can be used on the UNIVAC version to increase the amount of open core available for the BANDIT operations.)

Multipoint constraints (MPCs) and rigid elements are included in the BANDIT computations only when the BANDTMPC=1 (or 2) option is selected. (The use of the dependent grid points of MPCs and/or rigid elements is controlled by the BANDTDEP option.) However, as noted in Reference 1, it should be emphasized here that only in rare cases would it make sense to let BANDIT process MPCs

and rigid elements. The main reasons for this are that BANDIT does not consider individual degrees of freedom and, in addition, cannot distinguish one MPC set from another.

1.2.2.2.2 Cases for Which BANDIT Computations are Skipped

The BANDIT computations in NASTRAN are unconditionally skipped over if any of the following conditions is satisfied:

1. There are errors in input data.
2. The Bulk Data Deck contains any of the following types of input:
   a. Axisymmetric (CØNEAX, TRAPAX or TRIAAX) elements
   b. Fluid (FLUID2, FLUID3 or FLUID4) elements
   c. DMI (Direct Matrix Input) data
3. It is a substructure Phase 2 run.

1.2.2.2.3 BANDIT in Restarts

At the beginning of a NASTRAN job, the Preface (or Link 1) modules read and process the Executive, Case Control and Bulk Data Decks. The SEQGP cards generated by BANDIT are added directly to the NASTRAN data base (specifically, the GEØM1 file) at a later stage. Since these SEQGP cards are not part of the original Bulk Data Deck, they are not directly written on to the NPTP (New Problem Tape) in a checkpoint run and, therefore, are not available as such for use on the ØPTP (Old Problem Tape) in a restart.

In the light of the above comments, the following points about the use of BANDIT in NASTRAN restarts should be noted:

1. BANDIT is automatically skipped if the restart job has no input data changes with respect to the checkpoint job. However, the previously generated SEQGP cards, if any, are already absorbed into the NASTRAN data base (data blocks such as EQEXIN, SIL, etc.). A message is printed to inform the user that the BANDIT computations are not performed. (BANDIT can be executed if the restart job contains one or more of the appropriate BANDIT options on the NASTRAN card, e.g., NASTRAN BANDMTH = 2.)

2. BANDIT is executed (except for the cases indicated in Section 1.2.2.2.2) if the restart job has input data changes with respect to the checkpoint job, unless specifically suppressed by the user. (The BANDIT = -1 option on the NASTRAN card can be used to stop BANDIT execution unconditionally.)

1.2.3 Grid Point Properties

Some of the characteristics of the structural model are introduced as properties of grid points, rather than as properties of structural elements. Any of the various forms of direct

matrix input are considered as describing the structural model in terms of properties of grid points.

Thermal fields are defined by specifying the temperatures at grid points. The TEMP card is used to specify the temperature at grid points for use in connection with thermal loading and temperature-dependent material properties. The TEMPD card is used to specify a default temperature, in order to avoid a large number of duplicate entries on a TEMP card when the temperature is uniform over a large portion of the structure. The TEMPAX card is used for conical shell problems.

Mass properties may be input as properties of grid points by using the concentrated mass element (see Section 5.5 of the Theoretical Manual). The CØNM1 card is used to define a 6x6 matrix of mass coefficients at a geometric grid point in any selected coordinate system. The CØNM2 card is used to define a concentrated mass at a geometric grid point in terms of its mass, the three coordinates of its center of gravity, the three moments of inertia about its center of gravity, and its three products of inertia, referred to any selected coordinate system.

In dynamic analysis, mass, damping and stiffness properties may be provided, in part or entirely, as properties of grid points through the use of direct input matrices. The DMIG card is used to define direct input matrices for use in dynamic analysis. These matrices may be associated with components of geometric grid points, scalar points, or extra points introduced for dynamic analysis. The TF card is used to define transfer functions that are internally converted to direct matrix input. The DMIAX card is an alternate form of direct matrix input that is used for hydroelastic problems (see Section 1.7).

REFERENCES

1. Everstine, G. C., BANDIT User's Guide, COSMIC Program No. DOD-00033, May 1978.

2. Chan, G. C., "BANDIT in NASTRAN," Eleventh NASTRAN Users' Colloquium, NASA Conference Publication, May 1983, San Francisco, California, pp. 1-5.

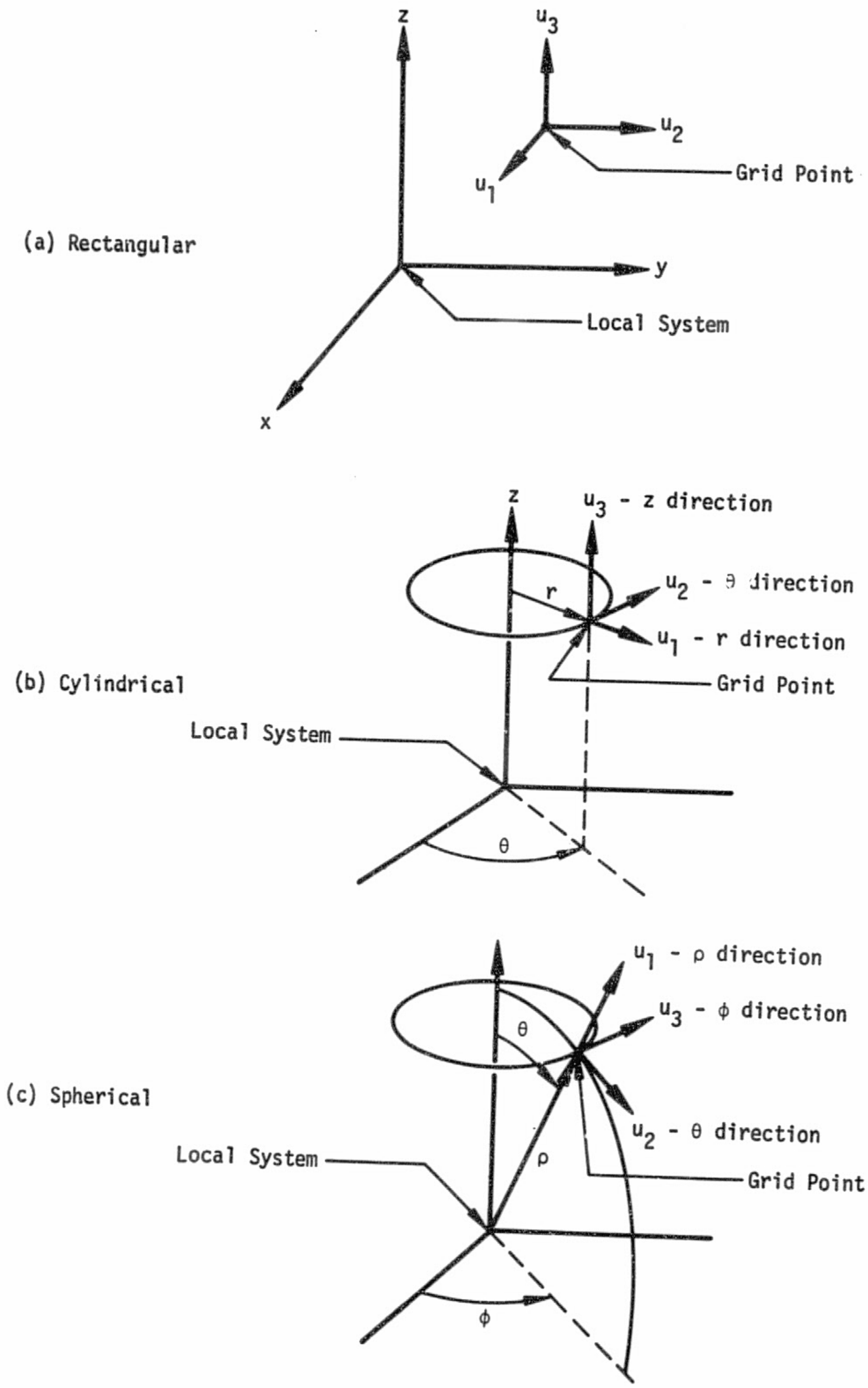

Figure 1. Displacement coordinate systems.

(a)
(b)
(c)

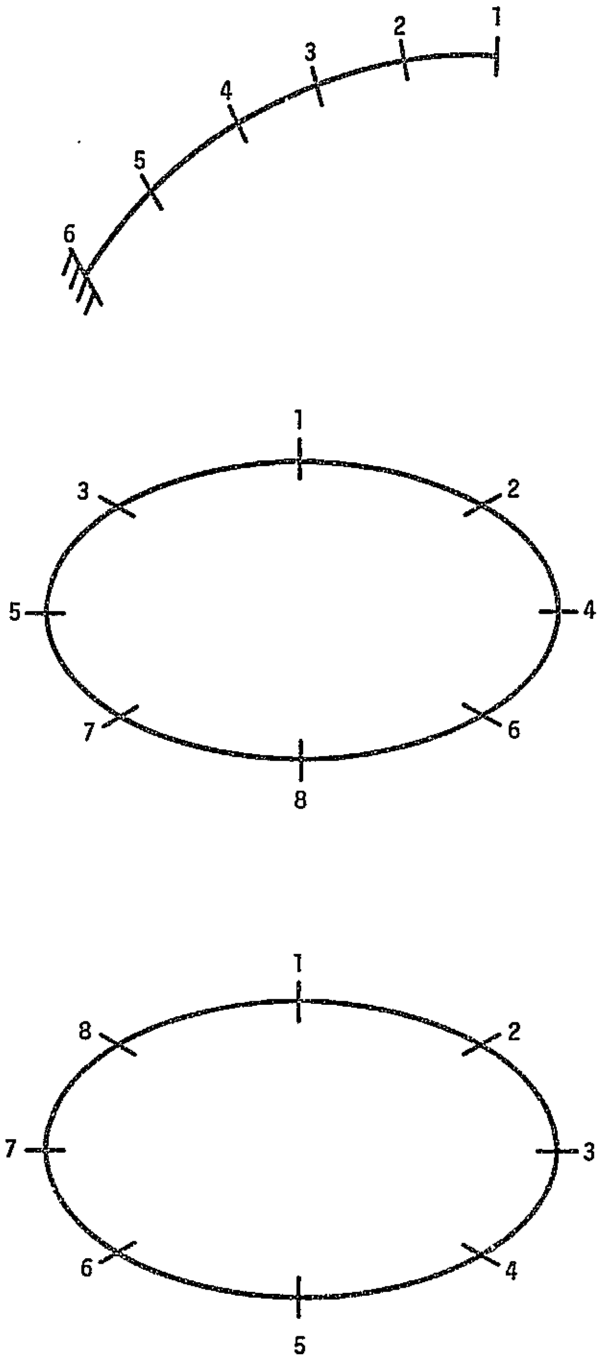

Figure 2. Grid point sequencing for one-dimensional systems.

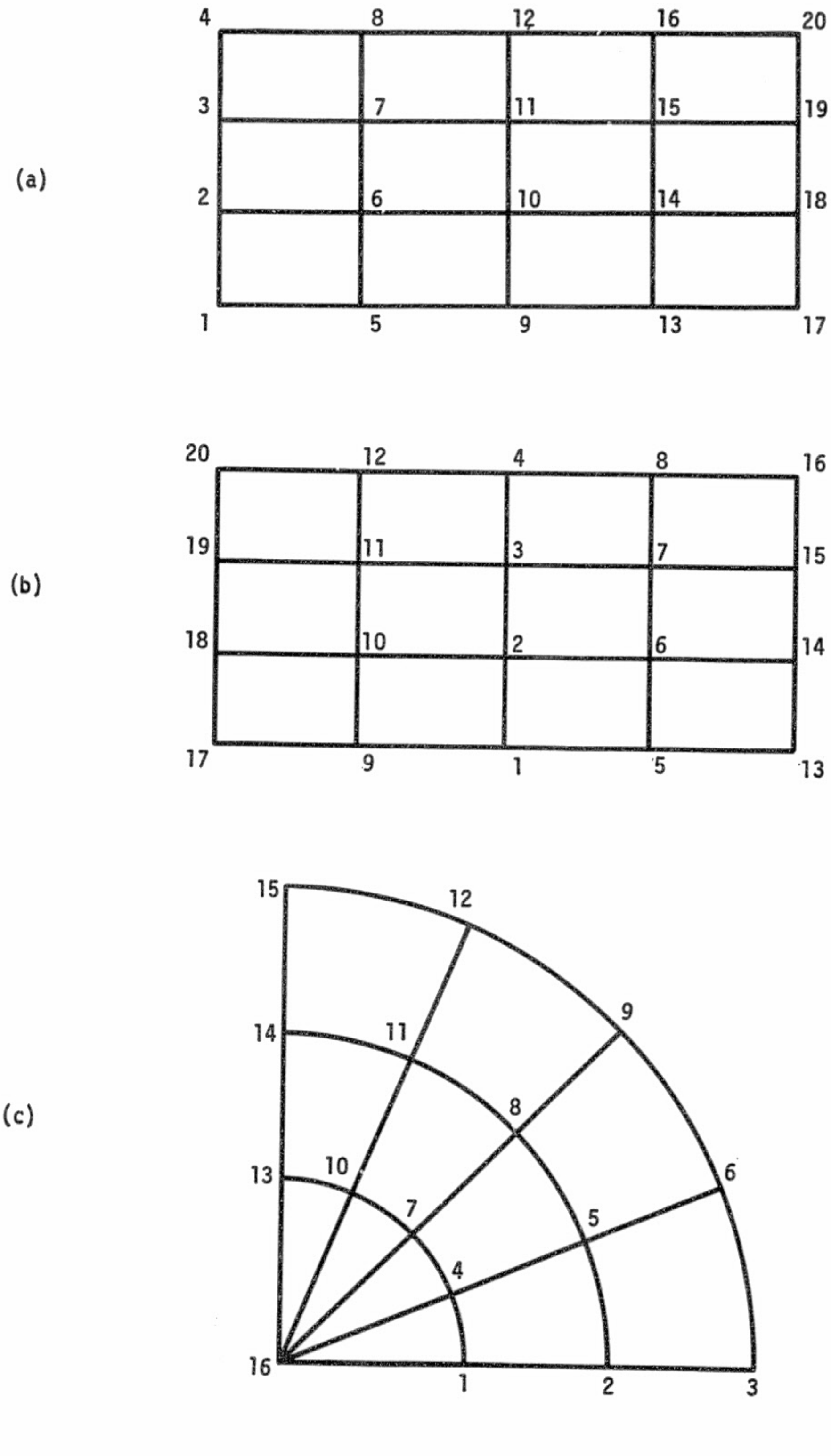

Figure 3. Grid point sequencing for surfaces.

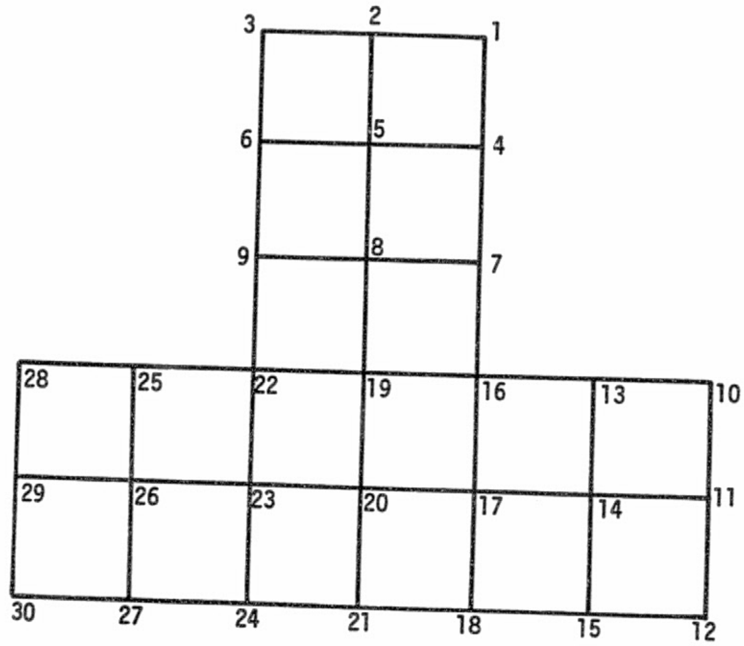

Figure 4. Grid point sequencing for substructures

```
X  X     X
   X  X  0  X
      X  0  0  X
         X  X  0  X
            X  X  0  X
               X  0  0  X
                  X  X  0                    X
                     X  X                    0        X
                        X                    0        0        X
                           X  X     X
                              X  X  0  X
                                 X  0  0  X
                                    X  X  0  X
                                       X  X  0  X
                                          X  0  0  X
                                             X  X  0  X        0
                                                X  X  0  X     0
                                                   X  0  0  X  0
                                                      X  X  0  X
                                                         X  X  0  X
                                                            X  0  0  X
                                                               X  X  0  X
                                                                  X  X  0  X
                                                                     X  0  0  X
                                                                        X  X  0  X
                                                                           X  X  0  X
                                                                              X  0  0  X
                                                                                 X  X  0
                                                                                    X  X
                                                                                       X
```

(Symmetric)

Figure 5. Matrix for substructure example

GRID POINTS

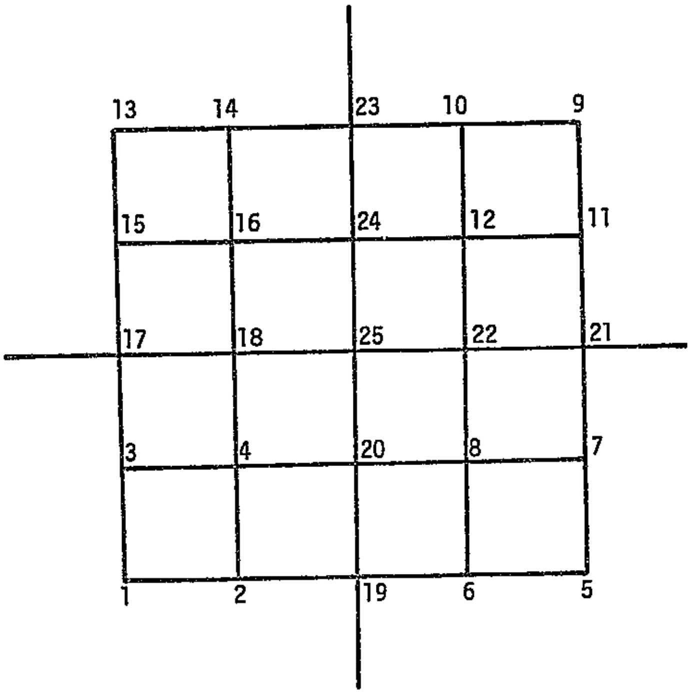

Figure 6. Grid point sequencing for square model

X	X	X																						
	X	0	X															X						
		X	X													X		0						
			X													0	X	0	X					
				X	X	X																		
					X	0	X											X						
						X	X											0		X				
							X											0	X	0	X			
								X	X	X														
									X	0	X											X		
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											X									0	X	0	X	
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															X	0	X					0	X	
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																	X	0	0			0	0	X
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																			X	0	0	0	0	X
																				X	X	0	0	0
																					X	0	0	X
																						X	X	0
																							X	X
																								X

(Symmetric)

Figure 7. Matrix for square model example

1.3 STRUCTURAL ELEMENTS

1.3.1 Element Definition

Structural elements are defined on connection cards that identify the grid points to which the elements are connected. The mnemonics for all such cards have a prefix of the letter "C", followed by an indication of the type of element, such as CBAR and CRØD. The order of the grid point identification defines the positive direction of the axis of a one-dimensional element and the positive surface of a plate element. The connection cards include additional orientation information when required. Except for the simplest elements, each connection card references a property definition card. If many elements have the same properties, this system of referencing eliminates a large number of duplicate entries.

The property definition cards define geometric properties such as thicknesses, cross-sectional areas, and moments of inertia. The mnemonics for all such cards have a prefix of the letter "P", followed by some, or all of the characters used on the associated connection card, such as PBAR and PRØD. Other included items are the nonstructural mass and the location of points where stresses will be calculated. Except for the simplest elements, each property definition card will reference a material property card.

In some cases, the same finite element can be defined by using different bulk data cards. These alternate cards have been provided for user convenience. In the case of a rod element, the normal definition is accomplished with a connection card (CRØD) which references a property card (PRØD). However, an alternate definition uses a CØNRØD card which combines connection and property information on a single card. This is more convenient if a large number of rod elements all have different properties.

In the case of plate elements, a different property card is provided for each type of element, such as membrane or sandwich plates. Thus, each property card contains only the information required for a single type of plate element, and in most cases, a single card has sufficient space for all of the property information. In order to maintain uniformity in the relationship between connection cards and property cards, a number of connection card types contain the same information, such as the connection cards for the various types of triangular elements. Also, the property cards for triangular and quadrilateral elements of the same type contain the same information.

The material property definition cards are used to define the properties for each of the materials used in the structural model. The MAT1 card is used to define the properties for isotropic materials. The MAT1 card may be referenced by any of the structural elements. The MATS1 card specifies table references for isotropic material properties that are stress dependent. The TABLES1 card defines a tabular stress-strain function for use in Piecewise Linear Analysis. The MATT1 card specifies table references for isotropic material properties that are temperature dependent. The TABLEM1, TABLEM2, TABLEM3, and TABLEM4 cards define four different types of tabular functions for use in generating temperature-dependent material properties.

The MAT2 card is used to define the properties for anisotropic materials. The MAT2 card may only be referenced by triangular or quadrilateral membrane and bending elements. The MAT2 card specifies the relationship between the inplane stresses and strains. The material is assumed to be infinitely rigid in transverse shear. The angle between the material coordinate system and the element coordinate system is specified on the connection cards. The MATT2 card specifies table references for anisotropic material properties that are temperature dependent. This card may reference any of the TABLEM1, TABLEM2, TABLEM3, or TABLEM4 cards.

The MAT3 card is used to define the properties for orthotropic materials used in the modeling of axisymmetric shells. This card may only be referenced by CTRIARG, CTRIAAX, CTRAPRG, CTRAPAX and PTØRDRG cards. The MATT3 card specifies table references for use in generating temperature-dependent properties for this type of material.

The GENEL card is used to define general elements whose properties are defined in terms of deflection influence coefficients or stiffness matrices, and which can be connected between any number of grid points. One of the important uses of the general element is the representation of part of a structure by means of experimentally measured data. No output data is prepared for the general element. Detail information on the general element is given in Section 5.7 of the Theoretical Manual.

Dummy elements are provided in order to allow the user to investigate new structural elements with a minimum expenditure of time and money. A dummy element is defined with a CDUMi (i = index of element type, $1 \le i \le 9$) card and its properties are defined with the PDUMi card. The ADUMi card is used to define the items on the connection and property cards. Detail instructions for coding dummy element routines are given in Section 6.8.5 of the Programmer's Manual.

1.3.2 Beam Elements

1.3.2.1 Simple Beam or Bar Element

The simple beam or bar element is defined with a CBAR card and its properties (constant over the length) are defined with a PBAR card. The bar element includes extension, torsion, bending in two perpendicular planes, and the associated shears. The shear center is assumed to coincide with the elastic axis. Any five of the six forces at either end of the element may be set equal to zero by using the pin flags on the CBAR card. The integers 1 to 6 represent the axial force, shearing force in Plane 1, shearing force in Plane 2, axial torque, moment in Plane 2, and moment in Plane 1, respectively. The structural and nonstructural mass of the bar are lumped at the ends of the element, unless coupled mass is requested with a PARAM CØUPMASS card (see PARAM bulk data card). Theoretical aspects of the bar element are treated in Section 5.2 of the Theoretical Manual.

The element coordinate system is shown in Figure 1a. End a is offset from grid point a an amount measured by vector $\vec{w}_a$ and end b is offset from grid point b an amount measured by vector $\vec{w}_b$. The vectors $\vec{w}_a$ and $\vec{w}_b$ are measured in the global coordinates of the connected grid point. The x-axis of the element coordinate system is defined by a line connecting end a to end b of the bar element. The orientation of the bar element is described in terms of two reference planes. The reference planes are defined with the aid of vector $\vec{v}$. This vector may be defined directly with three components in the global system at end a of the bar or by a line drawn from end a to a third referenced grid point. The first reference plane (Plane 1) is defined by the x-axis and the vector $\vec{v}$. The second reference plane (Plane 2) is defined by the vector cross product $(\vec{x} \times \vec{v})$ and the x-axis. The subscripts 1 and 2 refer to forces and geometric properties associated with bending in planes 1 and 2, respectively. The reference planes are not necessarily principal planes. The coincidence of the reference planes and the principal planes is indicated by a zero product of inertia (I_{12}) on the PBAR card. If shearing deformations are included, the reference axes and the principal axes must coincide. When pin flags and offsets are used, the effect of the pin is to free the force at the end of the element x-axis of the beam, not at the grid point. The positive directions for element forces are shown in Figure 1b. The following element forces, either real or complex (depending on the rigid format), are output on request:

1. Bending moments at both ends in the two reference planes.
2. Shears in the two reference planes.

3. Average axial force.

4. Torque about the bar axis.

The following real element stresses are output on request:

1. Average axial stress.

2. Extensional stress due to bending at four points on the cross-section at both ends. (Optional, calculated only if user enters stress recovery points on PBAR card.)

3. Maximum and minimum extensional stresses at both ends.

4. Margins of safety in tension and compression for the whole element. (Optional, calculated only if user enters stress limits on MAT1 card.)

Tensile stresses are given a positive sign and compressive stresses a negative sign. Only the average axial stress and the extensional stresses due to bending are available as complex stresses. The stress recovery coefficients on the PBAR card are used to locate points on the cross-section for stress recovery. The subscript 1 is associated with the distance of a stress recovery point from plane 2. The subscript 2 is associated with the distance from plane 1.

The use of the BARØR card avoids unnecessary repetition of input when a large number of bar elements either have the same property identification number or have their reference axes oriented in the same manner. This card is used to define default values on the CBAR card for the property identification number and the orientation vector for the reference axes. The default values are used only when the corresponding fields on the CBAR card are blank.

1.3.2.2 Curved Beam or Elbow Element

The curved beam or elbow element is a three-dimensional element with extension, torsion and bending capabilities and the associated shears. No offset of the elastic axis is allowed nor are pin releases permitted to eliminate the connection between motions at the ends of the element and the adjacent grid points.

The elbow element was initially developed to facilitate the analysis of pipe networks by using it as a curved pipe element. However, the input format is general enough to allow application to beams of general cross section. An important assumption in the development of the element is that the radius of curvature is much larger than the cross section depth.

The element is defined with a CELBØW card and its properties (constant over the length) are defined with a PELBØW card. There are six degrees of freedom at each end of the element: translations in the local x, y, z directions and rotations about the local x, y, z axes. The structural and nonstructural mass of the element are lumped at the ends of the element.

The specified properties of the elbow element are its area; its moments of inertia, I_1 and I_2 (the product of inertia is assumed to be zero); its torsional constant, J; the radius of curvature; the angle between end-a and end-b; the factors K_1 and K_2 for computing transverse shear stiffness; the nonstructural mass per unit length, NSM; the stress intensification factor, C; and the flexibility correction factors, K_x, K_y and K_z. The stress intensification factor C is applied to the bending stress only. The flexibility correction factors K_x, K_y and K_z are generally greater than 1.0 and are used as divisors to reduce the respective moments of inertia. These are discussed further towards the end of this section.

The material properties, obtained by reference to a materials properties table, include the elastic moduli, E and G, density, ρ, and the thermal expansion coefficient, α, determined at the average temperature of the element.

The plane of the element is defined by two grid points, A and B, and a vector $\vec{v}$ from grid point A directed toward the center of curvature. Plane 1 of the element cross section lies in this plane. Plane 2 is normal to Plane 1 and contains the vector $\vec{v}$. The area moments of inertia, I_1 and I_2, are defined as for the BAR element. The cross product of inertia, I_{12}, is neglected. This assumption requires that at least one axis of the element cross section be an axis of symmetry.

The following element forces are output on request:

- Bending moments at both ends in the two reference planes
- Transverse shear force at both ends in the two reference planes
- Axial force at both ends
- Torque at both ends

The following element stresses are output on request:

- Average axial stress at both ends
- Bending stresses at four points on the cross section at both ends. The points are specified by the user.
- Maximum and minimum extensional stresses at both ends.
- Margins of safety in tension and compression (Optional, output only if user enters stress limits on MAT1 card)

Stress Intensification Factor and Flexibility Correction Factors

When a plane pipe network, consisting of both straight and curved sections, is analyzed by

simple beam theory as an indeterminate system, the computed support reactions are greater than actually would be measured in an experiment. The apparent decrease in stiffness in such a case is due to an ovalization of the pipe in the curved sections. The ovalization also yields a stress distribution different from that computed by simple beam theory.

When a curved beam or elbow element is used as a curved pipe element, there are two factors available that can be specified to account for the differences in its behavior compared to curved beams. These are the stress intensification factor and the flexibility correction factors.

The maximum stress, σ_{max}, in a curved pipe element is given by

$$\sigma_{max} = C \frac{Mc}{I}$$

where C is a stress intensification factor,

M = bending moment,

c = fibre distance, and

I = plane (area) moment of inertia of the cross section.

In general, the factor C mentioned above may be regarded as a stress correction factor in curved beam analysis.

The effect of the ovalization of the pipe in curved sections is to reduce the stiffness parameter EI (E: modulus of elasticity) of the curved pipe to a fictitious value. Thus, for the elbow element,

$$(EI_1)' = \frac{EI_1}{K_y}, \ (K_y > 1.0), \text{ and}$$

$$(EI_2)' = \frac{EI_2}{K_z}, \ (K_z > 1.0), \text{ and}$$

where K_y and K_z are the stiffness correction factors corresponding to planes 1 and 2, respectively. The stiffness correction factor, K_z, corresponds to the torsional behavior and is generally taken to be 1.0.

1.3.3 Rod Element

The rod element is defined with a CRØD card and its properties with a PRØD card. The rod element includes extensional and torsional properties. The CØNRØD card is an alternate form that includes both the connection and property information on a single card. The tube element is a specialized form that is assumed to have a circular cross-section. The tube element is defined with a CTUBE card and its properties with a PTUBE card. The structural and nonstructural mass of the rod are lumped at the adjacent grid points unless coupled mass is requested with the PARAM CØUPMASS card (see PARAM bulk data card). Theoretical aspects of the rod element are treated in Section 5.2 of the Theoretical Manual).

The x-axis, of the element coordinate system, is defined by a line connecting end a to end b as shown in Figure 2. The axial force and torque are output on request in either the real or complex form. The positive directions for these forces are indicated in Figure 2. The following real element stresses are output on request:

1. Axial stress
2. Torsional stress
3. Margin of safety for axial stress
4. Margin of safety for torsional stress.

Positive directions are the same as those indicated in Figure 2 for element forces. Only the axial stress and the torsional stress are available as complex stresses.

Another kind of rod element is the viscous damper, that has extensional and torsional viscous damping properties rather than stiffness properties. The viscous damper element is defined with a CVISC card and its properties with a PVISC card. This element is used in the direct formulation of dynamic matrices.

1.3.4 Shear Panels and Twist Panels

The shear panel is defined with a CSHEAR card and its properties with a PSHEAR card. A shear panel is a two-dimensional structural element that resists the action of tangential forces applied to its edges, but does not resist the action of normal forces. The structural and nonstructural mass of the shear panel are lumped at the connected grid points. Details of the shear panel element are discussed in Section 5.3 of the Theoretical Manual.

The element coordinate system for a shear panel is shown in Figure 3a. The integers 1, 2,3, and 4 refer to the order of the connected grid points on the CSHEAR card. The element forces are output on request in either the real or complex form. The positive directions for these forces are indicated in Figure 3b. These forces consist of the forces applied to the element at the corners in the direction of the sides, kick forces at the corners in a direction normal to the plane formed by the two adjacent edges, and "shear flows" (force per unit length) along the four edges. The shear stresses are calculated at the corners in skewed coordinates parallel to the exterior edges. The average of the four corner stresses and the maximum stress are output on request in either the real or complex form. A margin of safety is also output when the stresses are real.

The twist panel performs the same function for bending action that the shear panel performs for membrane action. The twist panel is defined with a CTWIST card and its properties with a PTWIST card. In calculating the stiffness matrix, a twist panel is assumed to be solid. For built-up panels, the thickness in the PTWIST card must be adjusted to give the correct moment of inertia of the cross-section. If mass calculations are being made, the density will also have to be adjusted on a MAT1 card. The element coordinate system and directions for positive forces are shown in Figure 4. Stress recovery is similar to that for shear panels.

1.3.5 Plate and Membrane Elements

NASTRAN includes two different shapes of plate and membrane elements (triangular and quadrilateral) and two different stress systems (inplane and bending) which are uncoupled. There are different forms of elements available that are defined by connection cards as follows:

1. Plate (Bending) Elements
   a. CTRBSC - basic unit from which the bending properties of the other plate elements are formed.
   b. CTRPLT - triangular element with zero inplane stiffness and finite bending stiffness.

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c. CTRPLT1 - a higher order triangular element with zero inplane stiffness and finite bending stiffness. Uses quintic polynomial representation for transverse displacements and bilinear variation for temperature and thickness.

d. CQDPLT - quadrilateral element with zero inplane stiffness and finite bending stiffness.

2. Membrane (Inplane) Elements

a. CTRMEM - triangular element with finite inplane stiffness and zero bending stiffness.

b. CTRIM6 - triangular element with finite inplane stiffness and zero bending stiffness. Uses quadratic polynomial representation for membrane displacements and bilinear variation for temperature and thickness.

c. CQDMEM - quadrilateral element consisting of four overlapping CTRMEM elements.

d. CQDMEM1 - an isoparametric quadrilateral membrane element.

e. CQDMEM2 - a quadrilateral membrane element consisting of four nonoverlapping CTRMEM elements.

f. CIS2D8 - a quadriparabolic isoparametric membrane element. May be reduced to a triangular element under specified conditions.

3. Plate and Membrane Elements

a. CTRIA1 - triangular element with both inplane and bending stiffness. It is designed for sandwich plates which can have different materials referenced for membrane, bending and transverse shear properties.

b. CTRIA2 - triangular element with both inplane and bending stiffness that assumes a solid homogeneous cross-section.

c. CQUAD1 - quadrilateral element with both inplane and bending stiffness. It is designed for sandwich plates which can have different materials referenced for membrane, bending and transverse shear properties.

d. CQUAD2 - quadrilateral element with both inplane and bending stiffness that assumes a solid homogeneous cross-section.

Theoretical aspects of these elements are treated in Section 5.8 of the Theoretical Manual.

The properties for the above elements are defined on their associated Pxxxxxx cards (PTRBSC, PTRPLT, etc.). All of the properties of the elements are assumed uniform over their surfaces, except for the CTRIM6 and CTRPLT1 elements. Anisotropic material may be specified for all these elements. Transverse shear flexibility may be included for all bending elements on an optional basis, except for homogeneous elements (CTRIA2 and CQUAD2), where this effect is automatically included. Structural mass is calculated only for elements that specify a membrane thickness and is based only on the membrane thickness. Nonstructural mass can be specified for all plate elements, except the basic bending triangle. Only lumped mass procedures are used for membrane elements, except for the CIS2D8 element. Coupled mass procedures may be requested for elements that include bending stiffness with the PARAM CØUPMASS card (see PARAM bulk data card). Differential stiffness

matrices are generated for the following elements: CTRMEM, CTRIA1, CTRIA2, CQDMEM, CQUAD1, CQUAD2. The following elements may have nonlinear material characteristics in Piecewise Linear Analysis: CTRMEM, CTRIA1, CTRIA2, CQDMEM, CQUAD1, CQUAD2.

The element coordinate systems for the triangular and quadrilateral elements are shown in Figure 5. The integers 1, 2, 3, and 4 refer to the order of the connected grid points on the connection cards defining the elements. A similar connection scheme for elements with mid-side grid points would be defined by six or eight integers on the connection card. The angle θ is the orientation angle for anisotropic materials.

Average values of element forces are calculated for all plate elements (except the CTRPLT1) having a finite bending stiffness. The element forces for the CTRPLT1 are calculated at the corners and centroid of the element. The positive directions for plate element forces in the element coordinate system are shown in Figure 6a. The following element forces per unit of length, either real or complex, are output on request:

1. Bending moments on the x and y faces.

2. Twisting moment.

3. Shear forces on the x and y faces.

The CQDMEM2 is the only membrane element for which element forces are calculated. The positive directions for these forces are shown in Figure 3b, and the force output has the same interpretation as the force output for the shear palen discussed previously.

Average values of the membrane stresses are calculated for the triangular and quadrilateral membrane elements, with the exception of the CQDMEM1 and CTRIM6 elements. For the CQDMEM1 element, in which the stress field varies, the stresses are evaluated at the intersection of diagonals (in a mean plane if the element is warped.) For the CTRIM6 element, the stresses are calculated at the corners and centroid of the element. The positive directions for the membrane stresses are shown in Figure 6b. The stresses for the CQDMEM2 element are calculated in the material coordinate system. The material coordinate system is defined by the material orientation angle on the CQDMEM2 card. The stresses for all other membrane elements are calculated in the element coordinate system. For the CIS2D8 element, the stresses are computed at the Gaussian quadrature points and extrapolated to the grid points.

The following real membrane stresses are output on request:

1. Normal stresses in the x and y directions
2. Shear stress on the x face in the y direction
3. Angle between the x-axis and the major principal axis
4. Major and minor principal stresses
5. Maximum shear stress

Only the normal stresses and shearing stress are available in the complex form.

If an element has bending stiffness, the average stresses are calculated on the two faces of the plate for homogeneous plates and at two specified points on the cross-section for other plate elements. The distances to the specified points are given on the property cards. The positive directions for these fiber distances are defined according to the right-hand sequence of the grid points specified on the connection card. These distances are identified in the output and must be nonzero in order to obtain nonzero stress output. The same stresses are calculated for each of the faces as are calculated for membrane elements.

In the case of composite plate elements (CTRIA1, CTRIA2, CQUAD1 and CQUAD2 only), the stresses mentioned above can also be requested in a material coordinate system which is specified on a MAT1 or MAT2 card. In place of the fibre distances, the output in this case identifies the specified material coordinate system as well as an output code. This latter code is set to 1 or 2 according as the material x-axis or the y-axis is chosen as the reference axis.

The element stresses in material coordinate system computed above (for CTRIA1, CTRIA2, CQUAD1 and CQUAD2 elements) can also be requested at the connected grid points. These stresses (at grid points) are obtained by interpolation. The output code in this case is set to (10*N + projection code) where N is the number of independent points used in the interpolation and the projection code is an integer which is set to 1, 2 or 3 according as the material x-axis, y-axis or the z-axis is normal to projection.

In the case of composite plate elements (CTRIA1, CTRIA2, CQUAD1 and CQUAD2 only), strains and curvatures are also output on request. The options available and the output formats are similar to those available in the case of stresses as described above.

The quadrilateral elements are intended for use when the surfaces are reasonably flat and the geometry is nearly rectangular. For these conditions, the quadrilateral elements eliminate the modeling bias associated with the use of triangular elements, and quadrilaterals give more

accurate results for the same mesh size. If the surfaces are highly warped, curved or swept, triangular elements should be used. Under extreme conditions quadrilateral elements will give results that are considerably less accurate than triangular elements for the same mesh size. Quadrilateral elements should be kept as nearly square as practicable, as the accuracy tends to deteriorate as the aspect ratio of the quadrilateral increases. Triangular elements should be kept as nearly equilateral as practicable, as the accuracy tends to deteriorate as the angles become obtuse and as the ratio of the longest to the shortest side increases.

1.3.6 Axisymmetric Shell Elements

The properties of axisymmetric shells can be specified with either of two elements, the conical shell (CØNEAX) or the toroidal ring (TØRDRG). However, these cannot be used together in the same model. Also available for thick shells of revolution are the axisymmetric solid elements (TRIARG, TRAPRG, TRIAAX, and TRAPAX) which are described in the next section. Thin shell (TRSHL) modeling is described in Section 1.3.12.

1.3.6.1 Conical Shell (CØNEAX) Element

The properties of the conical shell element are assumed to be symmetrical with respect to the axis of the shell. However, the loads and deflections need not be axisymmetric, as they are expanded in Fourier series with respect to the aximuthal coordinate. Due to symmetry, the resulting load and deformation systems for different harmonic orders are independent, a fact that results in a large time saving when the use of the conical shell element is compared with an equivalent model constructed from plate elements. Theoretical aspects of the conical shell element are treated in Section 5.9 of the Theoretical Manual.

The conical shell element may be combined with TRIAAX and TRAPAX elements only. The existence of a conical shell problem is defined by the AXIC card. This card also indicates the number of harmonics desired in the problem formulation. Only a limited number of bulk data cards are allowed when using conical shell elements. The list of allowable cards is given on the AXIC card description in Section 2.4.2.

The geometry of a problem using the conical shell element is described with RINGAX cards instead of GRID cards. The RINGAX cards describe concentric circles about the basic z-axis, with their locations given by radii and z-coordinates as shown in Figure 7. The degrees of freedom defined by each RINGAX card are the Fourier coefficients of the motion with respect to angular position around the circle. For example the radial motion, u_r, at any angle, ϕ, is described by the equation:

$$u_r(\phi) = \sum_{n=0}^{N} u_r^n \cos n\phi + \sum_{n=0}^{N} u_r^{n*} \sin n\phi \,, \tag{1}$$

where u_r^n and u_r^{n*} are the Fourier coefficients of radial motion for the n-harmonic. For calculation purposes the series is limited to N harmonics as defined by the AXIC card. The first sum in the above equation describes symmetric motion with respect to the $\phi = 0$ plane. The second sum with the "starred" (*) superscripts describes the antisymmetric motion. Thus each RINGAX data card will produce six times (N+1) degrees of freedom for each series.

The selection of symmetric or antisymmetric solutions is controlled by the AXISYM card in the Case Control Deck. For general loading conditions, a combination of the symmetric and antisymmetric solutions must be made, using the SYMCØM card in the Case Control Deck (Section 2.3 of the User's Manual).

Since the user is rarely interested in applying his loads in terms of Fourier harmonics and interpreting his data by manually performing the above summations, NASTRAN is provided with special cards which automatically perform these operations. The PØINTAX card is used like a GRID card to define physical points on the structure for loading and output. Sections of the circle may be defined by a SECTAX card which defines a sector with two angles and a referenced RINGAX card. The PØINTAX and SECTAX cards define six degrees of freedom each. The implied coordinate system for these points is a cylindrical system (r, ϕ, z) and their applied loads must be described in this coordinate system. Since the displacements of these points are dependent on the harmonic motions, they may not be constrained in any manner.

The conical shell element is connected to two RINGAX points with a CCØNEAX card. The properties of the conical shell element are described on the PCØNEAX card. The RINGAX points must be placed on the neutral surface of the element and the points for stress calculation must be given on the PCØNEAX card relative to the neutral surface. Up to fourteen angular positions around the element may be specified for stress and force output. These values will be calculated midway between the two connected rings.

The structure defined with RINGAX and CCØNEAX cards must be constrained in a special manner. All harmonics may be constrained for a particular degree of freedom on a ring by using permanent single-point constraints on the RINGAX cards. Specified harmonics of each degree of freedom on a ring may be constrained with a SPCAX card. This card is the same as the SPC card except that a harmonic must be specified. The MPCAX, ØMITAX, and SUPAX data cards correspond the the MPC, ØMIT, and SUPØRT data except that harmonics must be specified. SPCADD and MPCADD cards may be used to combine constraint sets in the usual manner.

The stiffness matrix includes five degrees of freedom per grid circle per harmonic when transverse shear flexibility is included. Since the rotation about the normal to the surface is not included, either the fourth or the sixth degree of freedom (depending upon the situation) must be constrained to zero when the angle between the meridional generators of two adjacent elements is zero. When the transverse shear flexibility is not included, only four independent degrees of

freedom are used and the fourth and sixth degrees of freedom must be constrained to zero for all rings. These constraints can be conveniently specified on the RINGAX card.

The conical shell structure may be loaded in various ways. Concentrated forces may be described by FØRCE and MØMENT cards applied to PØINTAX points. Pressure loads may be input in the PRESAX data card which defines an area bounded by two rings and two angles. Temperature fields are described by a paired list of angles and temperatures around a ring as required by the TEMPAX card. Direct loads on the harmonics of a RINGAX point are given by the FORCEAX and MØMAX card. Since the implied coordinate system is cylindrical, the loads are given in the r, ϕ and z directions. The value of a harmonic load F_n is the total load on the whole ring of radius r. If a sinusoidal load per unit length of maximum value a_n is given, the value on the FØRCEAX card must be

$$F_n = 2\pi r a_n \qquad n = 0 , \tag{2}$$

$$F_n = \pi r a_n \qquad n > 0 . \tag{3}$$

Displacements of rings and forces in conical shell elements can be requested in two ways:

1. The harmonic coefficients of displacements on a ring or forces in a conical element.
2. The displacements at specified points or the average value over a specified sector of a ring. The forces in the element at specified azimuths or average values over specified sectors of a conical element.

Harmonic output is requested by ring number for displacements and conical shell element number for element forces. The number of harmonics that will be output for any request is a constant for any single execution. This number is controlled by the HARMØNICS card in the Case Control Deck (see Section 2.3).

The following element forces per unit of width are output either as harmonic coefficients or at specified locations on request:

1. Bending moments on the u and v faces
2. Twisting moments
3. Shearing forces on the u and v faces

The following element stresses are calculated at two specified points on the cross-section of the element and output either as harmonic coefficients or at specified locations on request:

1. Normal stresses in u and v directions
2. Shearing stress on the u face in the v direction

3. Angle between the u-axis and the major principal axis
4. Major and minor principal stresses
5. Maximum shear stress

The manner in which the data cards for the CØNEAX element (as well as for the TRAPAX and TRIAAX elements) are processed is described in Section 1.3.7.3.

1.3.6.2 Toroidal Ring (TØRDRG) Element

The coordinate system for the toroidal ring is shown in Figure 8. This cylindrical coordinate system is implied by the use of the toroidal element, and hence, no explicit definition is required. The toroidal element may use orthotropic materials. The axes of orthotropy are assumed to coincide with the element coordinate axes.

Deformation behavior of the toroidal element is described by five degrees of freedom for each of the two grid rings which it connects. The degrees of freedom in the implicit coordinate system are:

1. $\bar{u}$ - radial displacement
2. Not defined for toroidal element (must be constrained)
3. $\bar{w}$ - axial displacement
4. $w' = \frac{\partial w}{\partial \xi}$ slope in ξ-direction
5. $u' = \frac{\partial u}{\partial \xi}$ strain in ξ-direction
6. $w'' = \frac{\partial^2 w}{\partial \xi^2}$ curvature in $z\xi$-plane

The displacements $\bar{u}$ and $\bar{w}$ are in the basic coordinate system, and hence can be expressed in other local coordinate systems if desired. However, the quantities u', w' and w" are always in the element coordinate system.

The toroidal ring element connectivity is defined with a CTØRDRG card and its properties with a PTØRDRG card and, in the limit, this element becomes a cap element (see Section 5.10 of the Theoretical Manual). The integers 1 and 2 on Figure 8 refer to the order of the connected grid points on the CTØRDRG card. The grid points must lie in the r-$\bar{z}$ plane of the basic coordinate system and they must lie to the right of the axis of symmetry. The angles α_1 and α_2 in Figure 8 are the angles of curvature and are defined as the angle measured in degrees from the axis of

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symmetry to a line which is perpendicular to the tangent to the surface at grid points 1 and 2 respectively. For conic rings $\alpha_1 = \alpha_2$ and for cylindrical rings $\alpha_1 = \alpha_2 = 90$ degrees. Toroidal elements may be connected to form closed figures in the r-$\bar{z}$ plane, but slope discontinuities are not permitted at connection points.

The following forces, evaluated at each end of the toroidal element, are output on request:

1. Radial force
2. Axial force
3. Meridional moment
4. A generalized force which corresponds to the w' degree of freedom.
5. A generalized force which corresponds to the w" degree of freedom.

The first three forces are referenced to the global coordinate system and the two generalized forces are referenced to the element coordinate system. For a definition of the generalized forces see Section 5.10 of the Theoretical Manual.

The following stresses, evaluated at both ends and the midspan of each element, are output on request:

1. Tangential membrane stress (Force per unit length)
2. Circumferential membrane stress (Force per unit length)
3. Tangential bending stress (Moment per unit length)
4. Circumferential bending stress (Moment per unit length)
5. Shearing stress (Force per unit length)

The positive directions for these stresses are indicated in Figure 9.

1.3.7 Axisymmetric Solid Elements

Two sets of elements are provided for representing thick axisymmetric shell and/or solid structures (see Section 5.11 of the Theoretical Manual). The first set, the triangular ring TRIARG and trapezoidal ring TRAPRG, is restricted to axisymmetric applied loadings only. The second set is not restricted to axisymmetric loadings and, like the conical shell element, their displacements and loads are represented by coefficients of a Fourier series about the circumference. These elements, the TRIAAX and the TRAPAX, also define a triangular and a trapezoidal cross section respectively. The elements of one set may not be used together with elements of the other set nor with any other elements except the combination of TRIAAX and TRAPAX elements with the conical shell element (CØNEAX).

1.3.7.1 TRIARG and TRAPRG Elements

The triangular and trapezoidal ring elements may be used for modeling axisymmetric thick-walled structures of arbitrary profile. In the limiting case only the TRAPRG element may become a solid core element.

The coordinate systems for the triangular and trapezoidal ring elements are shown in Figures 10 and 11, respectively. The cylindrical system is implied by the use of these ring elements. Hence, no explicit definition of the basic cylindrical coordinate system is required. Cylindrical anisotropy is optional for the material properties in the ring elements. Orientation of the orthotropic axes in the (r,z) plane is specified by the angle Θ. The deformation behavior of the elements is described in terms of the translations in the r and z directions at each of the connected grid points. All other degrees of freedom must be constrained.

The triangular ring element is defined with a CTRIARG card. No property card is used for this element. The material property reference is given on the connection card. The integers 1, 2 and 3 in Figure 10 refer to the order of the connected grid points on the CTRIARG card. This order must be counter-clockwise around the element. The grid points must lie in the r-z plane of the basic cylindrical coordinate system, and they must lie to the right of the axis of symmetry.

The radial and axial forces at each connected grid point are output on request. The positive directions for these forces are shown in Figure 10. These are apparent element forces and they include any equivalent thermal loads. The stresses at the centroid of an element are output on request. The available quantities are the normal stresses in the radial, circumferential and axial directions, and the shear stress on the radial face in the axial direction. Positive stresses are in the positive direction on the positive face.

The trapezoidal ring element is defined with a CTRAPRG card in a manner similar to that for a triangular element. This element is similar to the triangular ring element. This element has the additional restriction that the element numbering must begin at the lower left hand corner of the element. Also, the parallel faces of the trapezoid must be perpendicular to the axis of symmetry (see Figure 11). This element can be used in the limiting case where the r coordinates associated with grid points 1 and 4 are zero. In this special case the element is referred to as a core element.

The forces at the four connected grid points are provided on request in a manner similar to that for a triangular element. In addition to providing the stresses at the four connected grid points of the trapezoid, similar stresses are provided at a point of average radius and average z-distance from the four points.

1.3.7.2 TRIAAX and TRAPAX Elements

The two solid of revolution elements which are provided for representing nonaxisymmetric loadings on axisymmetric structures with thick or solid cross sections are the TRIAAX and TRAPAX elements. These define a triangle and a trapezoidal cross section of the structure. They are functionally similar to the conical shell element (see Section 1.3.6) and physically similar to the TRAPRG and TRIARG axisymmetric ring elements described above (see Figures 10 and 11).

The elements are connected to RINGAX points which define displacement degrees of freedom represented by coefficients of a Fourier series about the circumference. Due to symmetry, the resulting load and deformation systems for the different harmonic orders are uncoupled, resulting in large time savings compared to a general three-dimensional model. Theoretical aspects of the solid of revolution elements are treated in Section 5.11 of the Theoretical Manual. Definitions of the Fourier series representation of the structural displacements and loads are given in Section 5.9 of the Theoretical Manual. As in the conical shell formulation, no other element types may be combined with these elements.

The following special case control cards, used also with the conical shell problem, are used with the solid of revolution elements:

AXISYM - Defines whether the cosine series, sine series or combination of displacements are to be calculated.

HARMØNICS - Limits the output to all harmonics up to and including the n^{th} harmonic, default is 0.

The geometry of a problem using these elements is defined by the RINGAX cards. The harmonic limit in the Fourier expansion is defined by the required AXIC card. The RINGAX card does not allow a zero radius. However, a small "hole" may be defined around the axis of revolution. To avoid inaccuracies, a warning is issued for each element whose inner radius is less than one-tenth its outer radius. Property cards PTRAPAX and PTRIAAX are used to identify the material and the circumferential locations for stress output. The material type is limited to MAT1 and MAT3 definitions. The following bulk data cards, also used with the conical shell elements, are available with the solid of revolution elements:

AXIC - Defines limit of displacement Fourier series.

SPCAX - Defines single point constraints and enforced displacements on specified degrees of freedom.

MPCAX - Defines multipoint constraints connecting specified degrees of freedom.

ØMITAX - Defines degrees of freedom to be removed by structural partitioning.

SUPAX - Defines free-body support points.

PØINTAX - Defines circumferential location on a RINGAX station for applied loading and/or output.

SECTAX - Defines a circumferential sector on a RINGAX station for distributed applied forces.

FØRCE - Defines a concentrated force at a PØINTAX or load per length at a SECTAX location on the structure.

FØRCEAX - Defines a generalized force directly on a specified harmonic of a RINGAX station.

PRESAX - Defines a pressure load.

TEMPAX - Defines a temperature distribution at a RINGAX point for thermal loading and temperature-dependent matrices.

The implied coordinate system for the solid of revolution elements is a cylindrical coordinate system (r, ϕ, z). The rotational degrees of freedom (components 4, 5 and 6) must be constrained.

The output quantities for the RINGAX points are the displacement coefficients for each harmonic. The output for the PØINTAX degrees of freedom are the sum of the harmonics giving the physical displacements at the point while the output for the SECTAX points are the average displacements over the circumferential sector. These quantities are available only in SØRT1 format.

The stress output for these elements is similar to that for the TRIARG and TRAPRG elements described above. However, since the stresses vary around the circumference, each element output includes the Fourier coefficients of stress for each harmonic followed by the stresses at the angular locations specified on the property card. Stresses are calculated at the centroid of the cross section on the TRIAAX element. Stresses are calculated at the four corners as well as at a fifth "grid point" on the TRAPAX element, which is located an average radius and average length from the four corner points.

1.3.7.3 Data Processing for the CØNEAX, TRAPAX and TRIAAX Axisymmetric Elements

The data cards submitted by the user for the CØNEAX, TRAPAX and TRIAAX axisymmetric elements are processed by the NASTRAN Preface to produce equivalent grid point, element connection, constraint and load data card images. Each specified harmonic, n, of the Fourier series solution

produces a complete set of these special data card images. In order to retain unique internal identification numbers for each harmonic, the user (or external) identification numbers are encoded by the following algorithms.

RINGAX Cards

NASTRAN (or internal) grid ID = User (or external) ring ID + 1,000,000 x n

(n = 1, 2, 3, ..., N, where N = highest harmonic defined on the AXIC card)

CØNEAX, TRAPAX and TRIAAX Connection Cards

NASTRAN (or internal) element ID = User (or external) element ID x 1,000 + n

(n = 1, 2, 3, ..., N)

The exact manner in which the above data cards as well as other data cards for these elements are processed by the NASTRAN Preface is fully described in Section 4.6.7 of the Programmer's Manual.

The user should use the NASTRAN (or internal) identification numbers (and not the user or external identification numbers) in specifying the data for plotting purposes. (See, for instance, the description of the SET card in Section 4.2.2.4.)

1.3.8 Scalar Elements

Scalar elements are connected between pairs of degrees of freedom (at either scalar or geometric grid points) or between one degree of freedom and ground. Scalar elements are available as springs, masses and viscous dampers. Scalar spring elements are useful for representing elastic properties that cannot be conveniently modeled with the usual metric structural elements. Scalar masses are useful for the selective representation of inertia properties, such as occurs when a concentrated mass is effectively isolated for motion in one direction only. The scalar damper is used to provide viscous damping between two selected degrees of freedom or between one degree of freedom and ground. It is possible, using only scalar elements and constraints, to construct a model for the linear behavior of any structure. However it is expected that these elements will be used only when the usual metric elements are not satisfactory. Scalar elements are useful for modeling part of a structure with its vibration modes or when trying to consider electrical or heat transfer properties as part of an overall structural analysis. The reader is referred to Sections 5.5 and 5.6 of the Theoretical Manual for further discussions on the use of scalar elements.

The most general definition of a scalar spring is given with a CELAS1 card. The associated properties are given on the PELAS card. The properties include the magnitude of the elastic spring, a damping coefficient, and a stress coefficient to be used in stress recovery. The CELAS2 defines a scalar spring without reference to a property card. The CELAS3 card defines a scalar spring that is connected only to scalar points and the properties are given on a PELAS card. The CELAS4 card defines a scalar spring that is connected only to scalar points and without reference to a property card. No damping coefficient or stress coefficient is available with the CELAS4 card.

Scalar elements may be connected to ground without the use of constraint cards. Grounded connections are indicated on the connection card by leaving the appropriate scalar identification number blank. Since the values for scalar elements are not functions of material properties, no references to such cards are needed.

The CDAMP1, CDAMP2, CDAMP3 and CDAMP4 cards define scalar dampers in a manner similar to the scalar spring definitions. The associated PDAMP card contains only a value for the scalar damper.

1.3.9 Mass

Inertia properties are specified directly as mass elements attached to grid points and indirectly as the properties of matrix structural elements. In addition, dynamic analysis mass matrix coefficients may be specified that are directly referred to the global coordinate system. Some portions of the mass matrix are generated automatically while other portions are not. Mass data may be assembled according to two different kinds of relationships: lumped mass assumptions or coupled mass considerations. Additional information on treatment of inertia properties is given in Section 5.5 of the Theoretical Manual.

1.3.9.1 Lumped Mass

The partitions of the lumped mass matrix are explained in Section 5.5.3 of the Theoretical Manual, but to aid the user the form is repeated here in Equation 1.

$$M = \left[\begin{array}{c|c} \text{Scalar} & \begin{array}{c}\text{1st}\\ \text{Moment}\end{array} \\ \hline \begin{array}{c}\text{1st}\\ \text{Moment}\end{array} & \begin{array}{c}\text{2nd}\\ \text{Moment}\end{array} \end{array}\right] = \left[\begin{array}{c:c} m_{ij} & N_{ij} \\ \hdashline N_{ij}^{T} & I_{ij} \end{array}\right] \qquad (1)$$

The only portion of the lumped mass matrix that is automatically generated is the scalar partition. This implies that no first moment and second moment terms for the lumped mass matrix are automatically generated. In this context, automatic generation means the calculation of the mass from the structural elements that are connected to a given grid point, solely from the information provided on the element connection and property card. All of the metric structural elements (rods, bars, shear panels, twist panels, plates, and shell elements) may have uniformly distributed structural and nonstructural mass. Structural mass is calculated from material and goemetric properties. The mass is assumed to be concentrated in the middle surface or along the neutral axis in the case of rods and bars, so that rotary inertia effects, including the torsional inertia of beams, are absent.

In the lumped mass method, the mass of an element is simply divided into equal portions and each portion is assigned to only one of the surrounding grid points. Thus, for uniform rods and bars, one-half of the mass is placed at each end; for uniform triangles, one-third of the mass is

placed at each corner; quadrilaterals are treated as two pairs of overlapping triangles (see the Theoretical Manual Sections 5.3 and 5.8). The lumped mass matrix is independent of the elastic properties of elements. There are no other automatic routines for providing mass terms for the lumped mass approach.

1.3.9.2 Coupled Mass

In the coupled mass approach, properties of mass pertaining to a single structural element include off-diagonal coefficients that couple action at adjacent grid points. For further amplification of the techniques used in the coupled mass approach see Section 5.5.3 of the Theoretical Manual. To invoke the automatic generation of the coupled mass matrix, the parameter CØUPMASS is indicated on the PARAM card. If selected coupled mass properties are desired only for certain element types, this is obtained by a second parameter call specifying the element. For further details see the PARAM bulk data card. When using CØUPMASS, the nonzero terms are generated in off-diagonal positions of the mass matrix corresponding generally to nonzero terms of the stiffness matrix. This implies that a mass matrix generated by the coupled mass approach will generally have a density and topology equivalent to that of the stiffness matrix.

Off-diagonal mass terms may also be created during Guyan reduction when the ØMIT or ASET bulk data cards are used to condense the stiffness and mass matrices. Any mass associated with the omitted degrees of freedom will be redistributed to the remaining degrees of freedom forming a coupled mass matrix. The use of multipoint constraints (MPC cards) with mass terms on the dependent degrees of freedom produces a similar effect. The mass on the dependent coordinate will be transformed to the connected independent coordinates, thereby coupling them together. Mathematically, these operations and the element coupled mass formulations described above are closely related.

1.3.9.3 Mass Input

In many cases it may be desired to add mass terms to the structure in addition to those generated by the structural elements. For instance, in a lumped mass formulation any additional masses involving rotational degrees of freedom must be independently calculated and input manually via bulk data cards.

The concentrated mass elements CØNM1 and CØNM2 may be used to add mass terms directly to a single grid point. The CØNM2 element is used to specify a rigid body with mass and inertia properties that is connected to a single grid point (offsets are allowed). The CONM1 element has a more general input format to allow directional mass terms.

The notation or the CONM1 card is explicit, that is, subscripting of each term spans the degree of freedom range from 1 through 6. On the CØNM2 card, double subscripting is used only for the second moment partition. Therefore, the correspondence for symbols between CØNM1 entries and CØNM2 entries for the second moment partition is as follows: I_{11}, I_{21}, I_{22}, I_{31}, I_{32} and I_{33} on the CØNM2 card (defined in Theoretical Manual section 5.5.2.2 by the integrals of Equations 13, 14 and 15) correspond to M_{44}, M_{54}, M_{55}, M_{64}, M_{65} and M_{66} on CØNM1 ($M_{54} = -I_{xy}$, $M_{64} = -I_{xz}$, $M_{65} = -I_{yz}$) with sign changes on the off-diagonal terms as shown in Equation 10 of the referenced section. The program multiplies each cross product of inertia term from CØNM2 user data by (-1) before assembling this data into the mass matrix, to make it correspond to the requirements of Equation 10.

An alternative to specifying mass information for the lumped mass method is to use the CMASSi and the PMASSi cards. This allows the option of treating mass as finite elements, one degree of freedom at a time. A particularly advantageous feature of the CMASSi card is the ability to couple mass terms between grid points and/or scalar points. When dynamic rigid formats are used, the direct matrix input (DMIG) may be used to supply grid point mass data. When mass information is entered via DMIG cards, it will remain dormant until activated by a call from Case Control via the M2PP card.

When a DMAP sequence is used or a rigid format is ALTERed, another form is available for presenting mass information via the DMI card. The DMI card is not recognized as a legitimate source of bulk data for the rigid formats, unless an ALTER is used.

In all cases a combination of mass input can be used. For instance, the translational inertias can be generated automatically by the element routines, while the first and second moment properties can be provided through CØNM2 cards. Some elements can be used to provide coupled mass properties through the CØUPMASS parameter, while other contributions to the same grid points can

be made by direct matrix input through DMIG cards. The information from these several sources will be summed in the formation of the final mass matrix.

1.3.9.4 Output from the Grid Point Weight Generator

The Grid Point Weight Generator (GPWG) module computes the rigid body mass properties of an entire structure with respect to a user specified point and with respect to the center of mass.

Output from the module is requested by a PARAM card in the Bulk Data Deck which specifies from which grid point mass computations are to be referenced. Optionally, the absence of a specific grid point automatically causes the origin of the basic coordinate system to be utilized as a reference. The mass properties are initially defined in the basic coordinate system. Subsequently, the mass properties are transformed to principal mass axes and to principal inertia axes. The actual printout is composed of several elements. These are

1. Title MØ - RIGID BØDY MASS MATRIX IN BASIC CØØRDINATE SYSTEM

This is the rigid body mass matrix of the entire structure in the basic coordinate system with respect to a reference point chosen by the analyst.

2. Title S - TRANSFØRMATION MATRIX FØR SCALAR MASS PARTITIØN

S is the transformation from the basic coordinate system to the set of principal axes for the 3 x 3 scalar mass partition of the 6 x 6 mass matrix. The principal axes for just the scalar partition are known as the principal mass axes.

3. Title X-C.G. Y-C.G. Z-C.G.

It is possible in NASTRAN to assemble a structural model having different values of mass in each coordinate direction at a grid point. This can arise for example assembling scalar mass components or from omitting some components by means of bar element pin flags. Consequently three distinct mass systems are assembled one in each of the three directions of the principal mass axes (the S system). This third tabulation has five columns. The first column lists the axis direction in the S coordinates. The second column lists the mass associated with the appropriate axis direction. The final three columns list the x, y, and z coordinate distances from the reference point to the center of mass for each of the three mass systems.

4. Title I(S) - INERTIAS RELATIVE TØ C.G.

This is the 3 x 3 mass moment of inertia partition with respect to the center of gravity referred to the principal mass axes (the S system). This is not necessarily a diagonal matrix because the determination of the S system does not involve second moments. The values of

inertias at the center of gravity are found from the values at the reference point by employing the parallel axes rule.

5. Title I(Q) - PRINCIPAL INERTIAS

The principal moments of inertia at the center of gravity are displayed in matrix form with reference to the Q system of axes. The Q system is obtained from an eigenvalue analysis of the I(s) matrix.

6. Title Q - TRANSFØRMATION MATRIX --I(Q) = QT*I(S)*Q

Q is the coordinate transformation between the S axes and the Q axes.

1.3.9.5 Bulk Data Cards for Mass

A summary chart is given in Table 1 to help in the selection of the method of input for a given type of mass information. Descriptions of individual cards for the entering of mass information into the bulk data are listed here:

1. Element data from the combined sources of C(-), P(-), and MATi cards will automatically cause the translational mass (scalar) terms of the mass matrix to be generated, provided a density value and/or a nonstructural density factor is entered.
2. The MASSi cards define scalar masses. CMASSi cards define connections between a pair of degrees of freedom (at either scalar or geometric grid points) or between one degree of freedom and ground. Thus, $f_1 = m(x_1 - x_2)$ where x_2 may be absent. The CMASSi cards (i = 1 through 4) are necessary whenever scalar points are used. PMASSi cards define mass property magnitudes. Other applications include selective representations of inertia properties, such as occur in shell theory where in-plane inertia forces are often ignored.
3. The CØNM2 card defines the properties of a solid body: m, its mass, x_1, x_2, x_3, the three coordinates of its center of gravity offset with respect to the grid point, I_{11}, I_{22}, I_{33}, its three moments of inertia and I_{12}, I_{13}, I_{23}, and its three products of inertia, all with respect to any (selected) coordinate system. If a local cylindrical or a spherical coordinate system is chosen to define the mass properties, the offset distances of the mass c.g. from the grid point are measured along the axes(r,Θ,z or ρ,Θ,Φ) defined at the grid point in that local system. Also note, that the mass properties of inertia are computed relative to a set axes at the mass c.g. which are parallel to those r,Θ,z or ρ,θ,ϕ axes at that grid point. The CØNM2 element routine uses the parallel axis theorem to

transform inertias with respect to the center of gravity to inertias with respect to the grid point. Section 5.5.2.1 of the Theoretical Manual describes how to treat the signs of cross products of inertia terms on CØNM2 cards.

4. The CØNM1 card defines a 6 x 6 matrix of mass coefficients at a geometric grid point in any selected coordinate system. Since the only restrictions are that the matrix be real and symmetric, there are 21 possible independent coefficients. The CØNM1 card therefore permits somewhat more general inertia relationships than those of a solid body which has only 10 independent inertia properties. This should be remembered in applications requiring unique centers of gravity, such as in the calculation of centrifugal forces. See Section 5.5.2.5 of the Theoretical Manual for a discussion of inertia properties resulting from CØNM1 card input.

5. The DMIG (or DMIGAX for axisymmetric structures) card accomodates matrix entries by grid point and component. This is a general card that can be used for mass, stiffness, or damping matrices. It becomes particularized to mass when the name given to the matrix is called by an M2PP card in Case Control. Data defined by this card will be recognized as admissible only when used with dynamic rigid formats 7 through 12.

6. The DMI card is used to assign values according to row-column positions in a matrix. This is a general card for any kind of matrix which becomes particularlized to mass when the name given to the matrix is called from a DMAP statement. Data defined by this card will be recognized as admissible only when used in a DMAP sequence or in an ALTER to a rigid format.

7. The COUPMASS entry on the PARAM card will activate the "consistent" mass matrix algorithms in the element routines which generate mass coupling properties between grid points. There are three options available to regulate whether the coupling properties are generated for all or some types of elements (see PARAM bulk data card). A set of entries for a second PARAM card of the form CP(element name) are available for use in connection with CØUPMASS for selecting the element types for which coupling terms will be computed.

8. The ØMIT (or ØMIT1, or ØMITAX for axisymmetric structures, or ASET for obverse operations) card will cause the initially-generated mass matrix to be condensed from the omitted degrees of freedom to the remaining degrees of freedom. The condensing process generally produces a mass term in every matrix position in which there is a nonzero stiffness term in the corresponding reduced stiffness matrix.

9. The GRDPNT entry on the PARAM card will activate the Grid Point Weight Generator (GPWG) module previously discussed. It will treat the mass properties of the entire structure as though the structure were rigid and it will determine the translational (scalar) mass properties, the first and second moment properties of the rigid body structure and the center of gravity distances with respect to the user specified reference grid points. It also computes the 6 x 6 matrix of mass properties with respect to the center of mass and the orientation of the principal mass axes.

Table 1. Bulk Data Card Choices for Mass Properties Versus Method of Mass Representation.

<table>
<tr><th rowspan="3">Representation Method / Mass Property</th><th colspan="4">Lumped</th><th colspan="2">Coupled</th><th rowspan="3">Grid Point Weight Generator (Total Structure)</th></tr>
<tr><th rowspan="2">Automatic</th><th colspan="3">Manual</th><th rowspan="2">Automatic</th><th rowspan="2">Manual</th></tr>
<tr><th>All R.F.'s</th><th>R.F.'s 7, 8, 9</th><th>DMAP or R.F. ALTER</th></tr>
<tr><td>Translational Mass (Scalar)</td><td>Element Routines
C (element) +
P (element) +
MATi
for structural and nonstructural contributions</td><td>MASSi
CØNM1
CØNM2</td><td>MASSi
CØNM1
CØNM2
DMIG
DMIGAX</td><td>DMI</td><td rowspan="3">PARAM <u>CØUPMASS</u> +
PARAM <u>CP</u> (element)
ØMIT
ØMIT1
ØMITAX
ASET</td><td rowspan="3">DMIG
DMIGAX</td><td rowspan="3">PARAM <u>GRDPNT</u></td></tr>
<tr><td>First Moment</td><td></td><td>MASSi
CØNM1
CØNM2</td><td>MASSi
CØNM1
CØNM2
DMIG
DMIGAX</td><td>DMI</td></tr>
<tr><td>Second Moment</td><td></td><td>MASSi
CØNM1
CØNM2</td><td>MASSi
CØNM1
CØNM2
DMIG
DMIGAX</td><td>DMI</td></tr>
<tr><td>All Order Moments and Off-Diagonal Properties Between Grid Points</td><td colspan="4"></td><td>PARAM <u>CØUPMASS</u> +
PARAM CP (element)
ØMIT
ØMIT1
ØMITAX
ASET</td><td>DMIG
DMIGAX</td><td></td></tr>
</table>

1.3.10 Solid Polyhedron Elements

Three types of solid polyhedron elements are provided for the general solid structures (see Section 1.3.7 for axisymmetric structures with axisymmetric loads). These elements (see Figure 12) are a tetrahedron, a wedge and a hexahedron. The theory is given in Section 5.12 of the Theoretical Manual. These elements can be used with all other NASTRAN elements, except the axisymmetric elements. Connections are made only to displacement degrees of freedom at the grid points.

The elements are defined by CTETRA, CWEDGE, CHEXA1, and CHEXA2 connection cards. The user should specify grid locations such that the quadrilateral faces are nearly planar. No special element coordinate system is required. The only properties required are material properties, thus no PID card is referenced; direct reference is made to a MID card. For thermal stress problems, the temperature is assumed to be the average of the connected grid points. Differential stiffness, buckling, and piecewise linear analyses have not been implemented.

The output stresses are given in the basic coordinate system. In addition to the six normal and shear stresses, output also includes the pressure

$$p_o = -\frac{1}{3}(\sigma_x + \sigma_y + \sigma_z)$$

and the octahedral stress

$$\sigma_o = \frac{1}{3}\left[(\sigma_x - \sigma_y)^2 + (\sigma_y - \sigma_z)^2 + (\sigma_z - \sigma_x)^2 + 6\tau_{yz}^2 + 6\tau_{zx}^2 + 6\tau_{xy}^2\right]^{1/2}$$

The stresses in the tetrahedra are constant. The stresses in the wedge and the hexahedron are obtained as the weighted average of the stresses in the subtetrahedra. The weighting factor for each tetrahedra is proportional to its volume.

1.3.11 Isoparametric Solid Hexahedron Elements

Three types of isoparametric solid hexahedron elements are provided for general solid structures. These elements (see Figure 13) are a linear, a quadratic, and a cubic isoparametric hexahedron. The theory is given in Section 5.13 of the Theoretical Manual. These elements can be used with all other NASTRAN elements, except the axisymmetric elements. Connections are made only to the translational degrees of freedom at the grid points. The elements are defined by CIHEX1, CIHEX2, and CIHEX3 connection cards. All three of these cards reference the PIHEX property card. These elements may use anisotropic materials by reference to a MAT6 card on the PIHEX card.

The isoparametric solid hexahedron elements allow the user to accurately define a structure with fewer elements and grid points than might otherwise be necessary with simple constant strain solid elements. The linear element generally gives best results for problems involving mostly shear deformations, and the higher order elements give good results for problems involving both shearing and bending deformations. Only a coupled mass matrix is generated to retain the inherent accuracy of the elements. Temperature, temperature-dependent material properties, displacements, and stresses may vary through the volume of the elements. The values at interior points of the element are interpolated using the isoparametric shape function. For best results, the applied grid point temperatures should not have more than a "gentle" quadratic variation in each of the three dimensions of the element. If the element has non-uniform applied temperatures, or if it is not a rectangular parallelopiped, three or more integration points should be specified on the PIHEX card. Severely distorted element shapes should be avoided.

Stiffness, mass, differential stiffness, structural damping, conductance, and capacitance matrices may be generated with these elements. Piecewise linear analysis has not been implemented.

The output stresses are given in the basic coordinate system. The stresses are assumed to vary through the element. Therefore, stresses are computed at the center and at each corner grid point of these elements. For the quadratic and cubic elements, they are also computed at the midpoint of each edge of the element. In addition to the six normal and shear stresses, output also includes the principal stresses (S_x, S_y, and S_z), the direction cosines of the principal planes, the mean stress

$$\sigma_n = -\frac{1}{3}(\sigma_x + \sigma_y + \sigma_z) \quad ,$$

and the octahedral shear stress

$$\sigma_o = \left\{\frac{1}{3}\left[(S_x + \sigma_n)^2 + (S_y + \sigma_n)^2 + (S_z + \sigma_n)^2\right]\right\}^{1/2} \quad .$$

1.3.12 Shallow Shell Element

A higher order shallow triangular shell element (TRSHL) formulated from the TRIM6 and TRPLT1 elements is available. The inplane and bending properties are coupled and the geometry of the element may be curved. If the element is flat and either the inplane or bending properties are negligible, the element degenerates to the TRPLT1 or TRIM6 element, respectively.

The element has grid points at the vertices and at the midpoints of the sides of the triangle (see Figure 14). At each grid point, there are five degrees of freedom in the element coordinate system; viz., the membrane displacements, u and v, parallel to the x and y axes, the transverse displacement, w, in the z-direction normal to the x-y plane (with positive direction outward from the paper) and the rotations of the normal to the shell, α and β, about the x-z and y-z planes (with positive directions following from the right-hand rule). The element, thus, has 30 degrees of freedom in the element coordinate system.

The membrane displacements, u and v, for the shell are expressed as quadratic polynomials and are the same as for the higher order membrane triangular element, TRIM6. The displacement function for the normal deflection, w, is taken as a quintic polynomial as in the higher order bending triangular element, TRPLT1. The geometry of the shell surface is approximated by a quadratic polynomial in basic coordinates. Shallow shell theory is used to include the membrane-bending coupling effects. Thus, the element should be used only in cases where the shell is truly shallow. However, reasonably good accuracy is seen even when the elements are used to analyze shells that are only marginally shallow. The user is cautioned, however, to be careful while interpreting results obtained when the shell analyzed is very deep. Due to the excessive computation time associated with such calculations, the transverse shear flexibility is not taken into account in the element formulation. Further discussion of this element is treated in Section 5.14 of the Theoretical Manual.

The connectivity of this element is described by a CTRSHL card and the properties are defined by a PTRSHL card. The element may be used in the statics, normal modes, and differential stiffness rigid formats. Loads may be mechanical or thermal.

Element forces per unit width are output for the following quantities:

1. Bending moments on the x and y faces
2. Twisting moment
3. Shear forces on the x and y faces

The element forces are calculated at the three corners and the centroid. The sign conventions for these forces are the same as previously discussed in Section 1.3.5.

Stresses are output for the following quantities:

1. Normal stresses in the x and y directions
2. Shear stress on the x face in the y direction
3. Angle between the x-axis and the major principal axis
4. Major and minor principal stresses (zero shear)
5. Maximum shear stress

The stresses will be calculated at the specified fibre distances from the elastic axis defined on the property card and are always calculated at the top and bottom fibres for the centroid of the element. The sign conventions for the stresses are the same as previously discussed in Section 1.3.5.

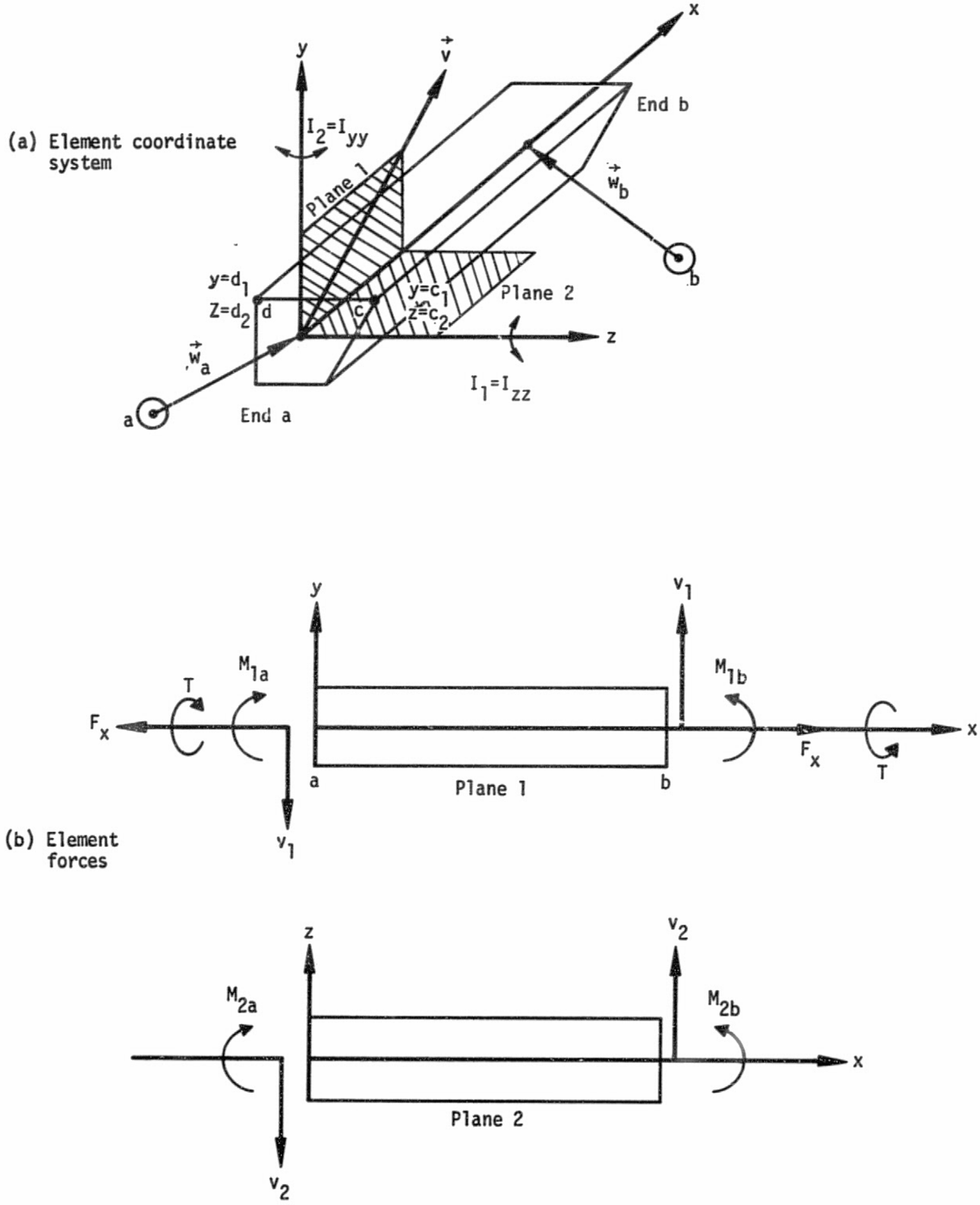

Figure 1. Bar element coordinate system and element forces.

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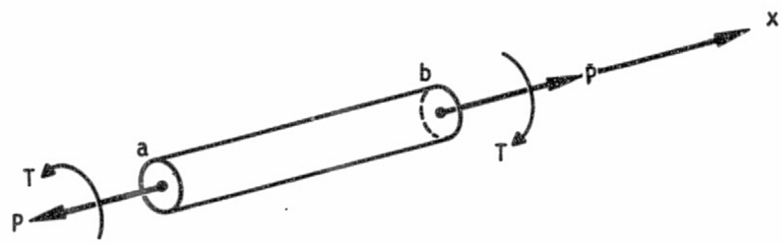
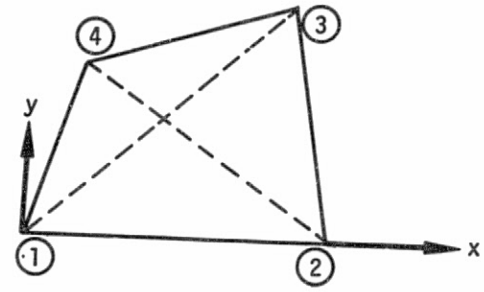
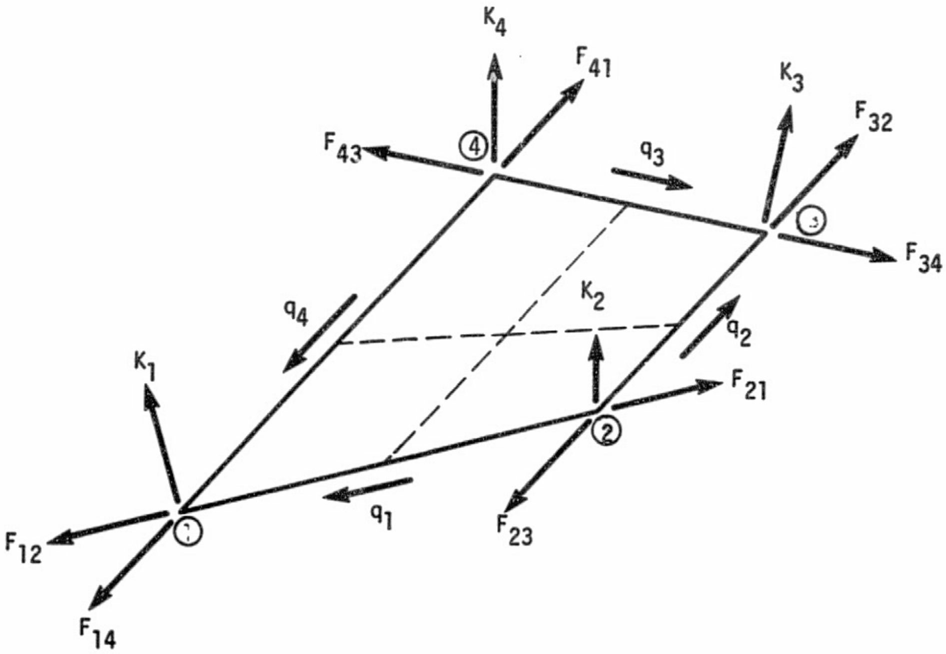


Figure 2. Rod element coordinate system and element forces.



(a) Coordinate System.



(b) Corner forces and shear flows.

Figure 3. Coordinate system and element forces for shear panel and CQDMEM2 elements.

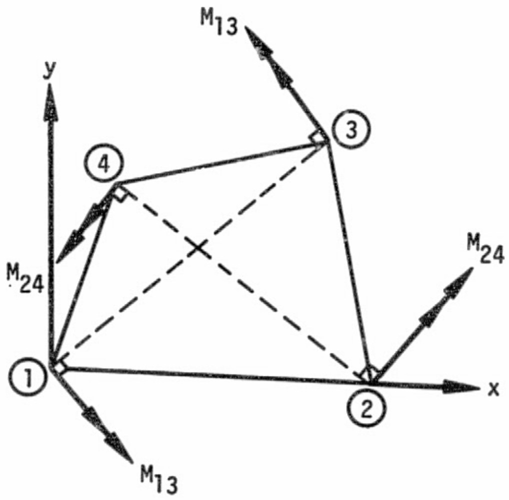
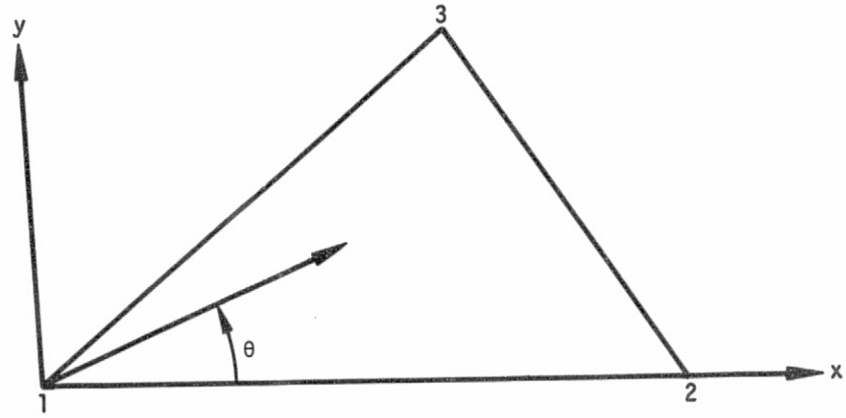
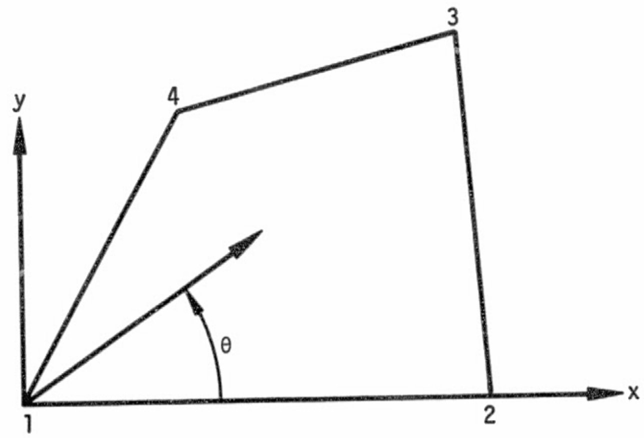


Figure 4. Twist panel coordinate system and element forces.

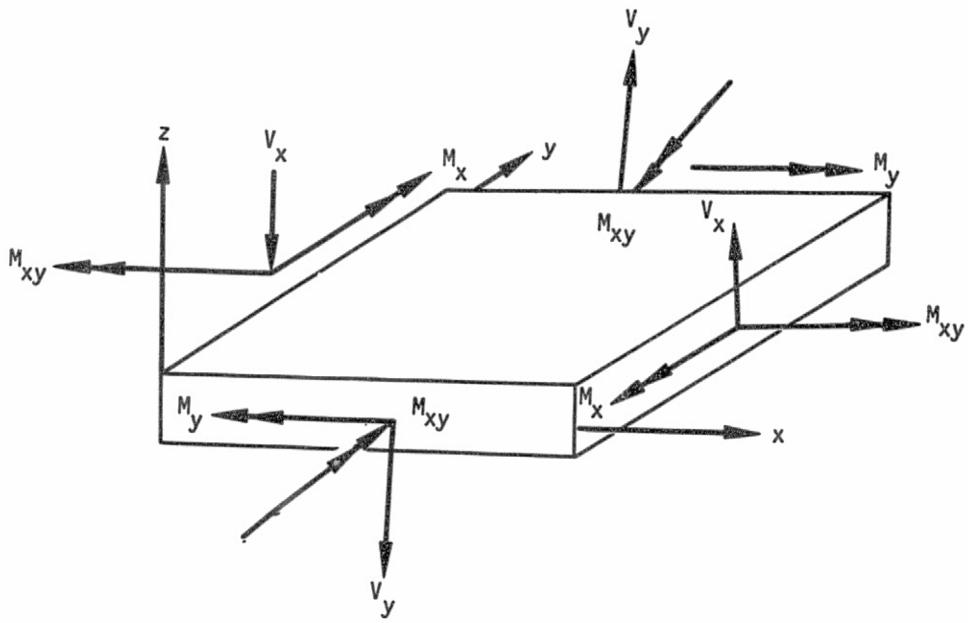


(a)

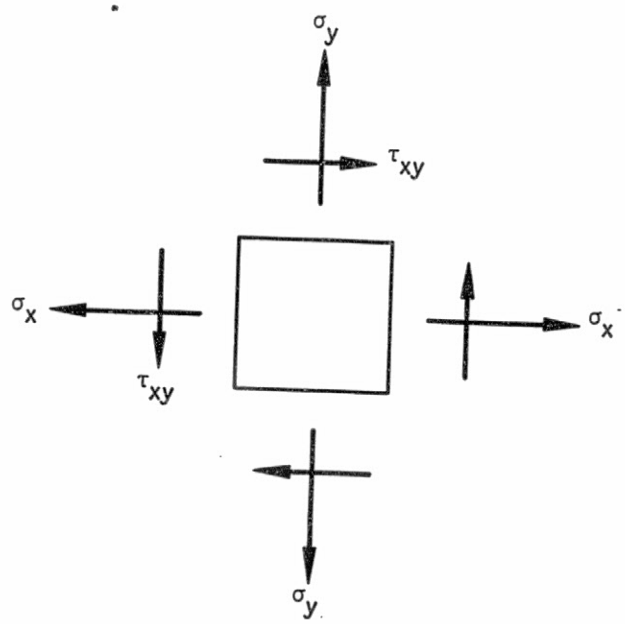


(b)

Figure 5. Plate and membrane element coordinate systems.



(a) Plate element forces.



(b) Membrane element stresses.

Figure 6. Forces and stresses in plate and membrane elements.

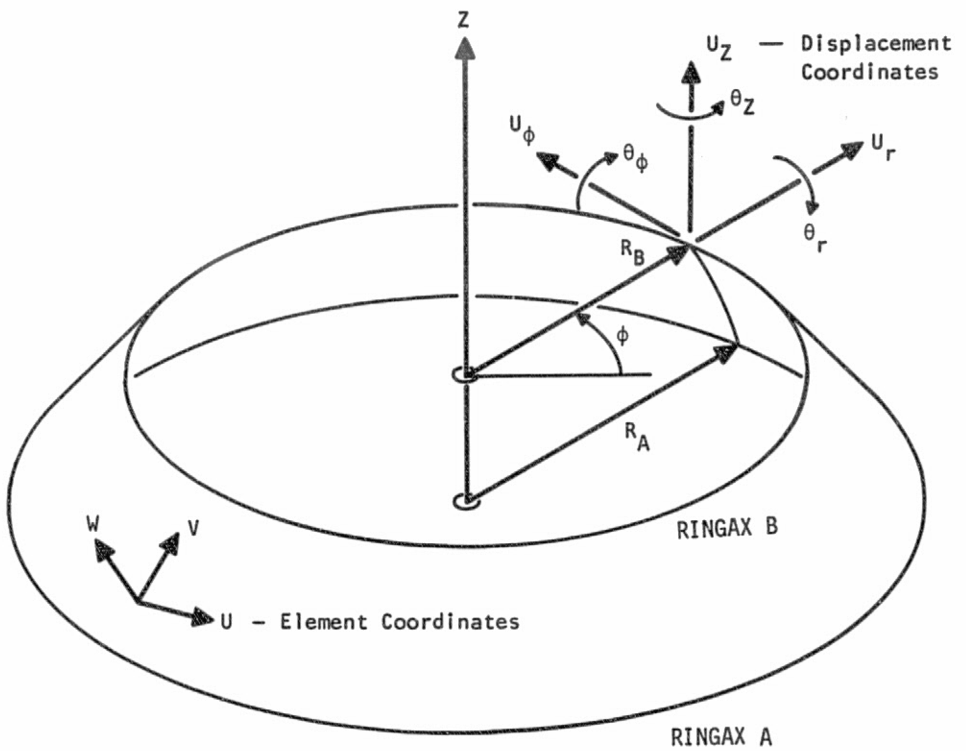


Figure 7. Geometry for conical shell element.

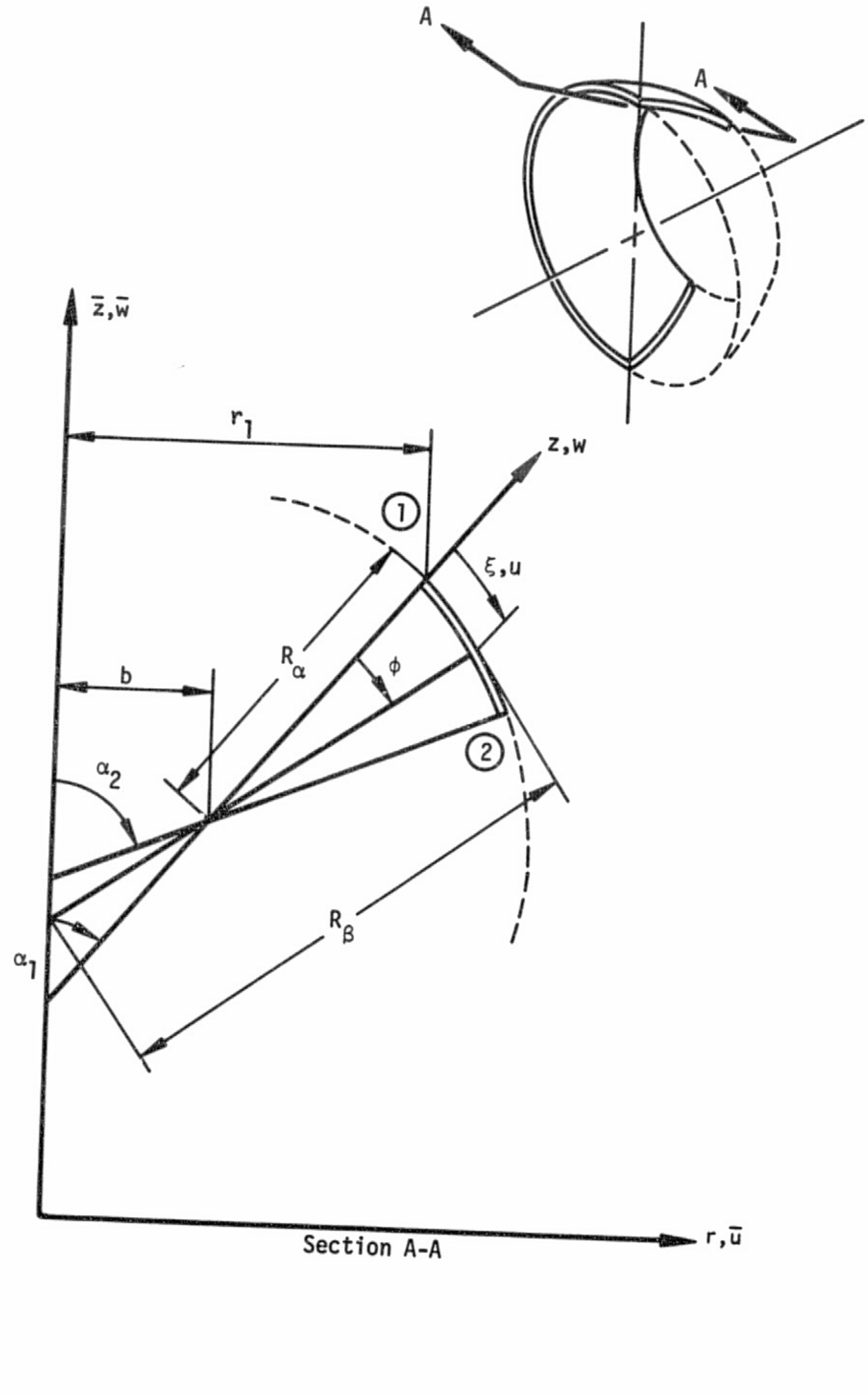


Figure 8. Toroidal ring element coordinate system.

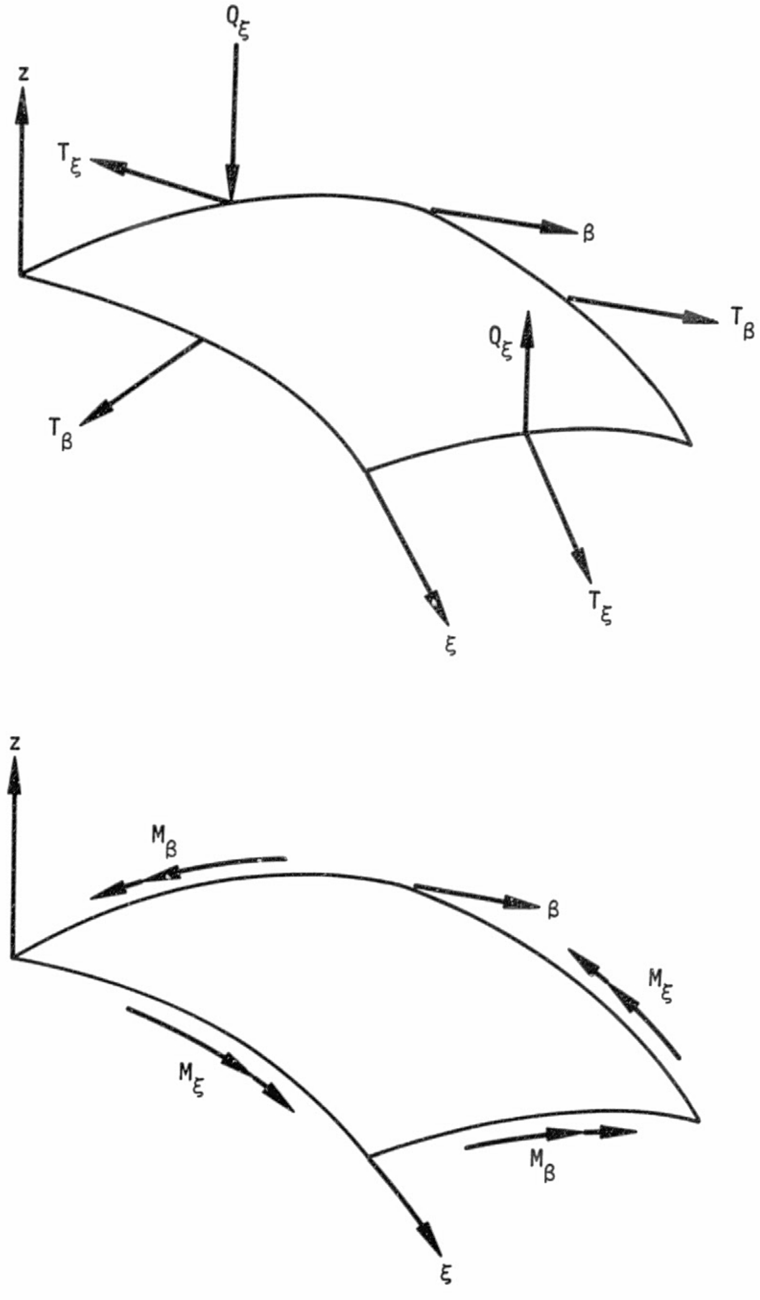


Figure 9. Stresses for toroidal element.

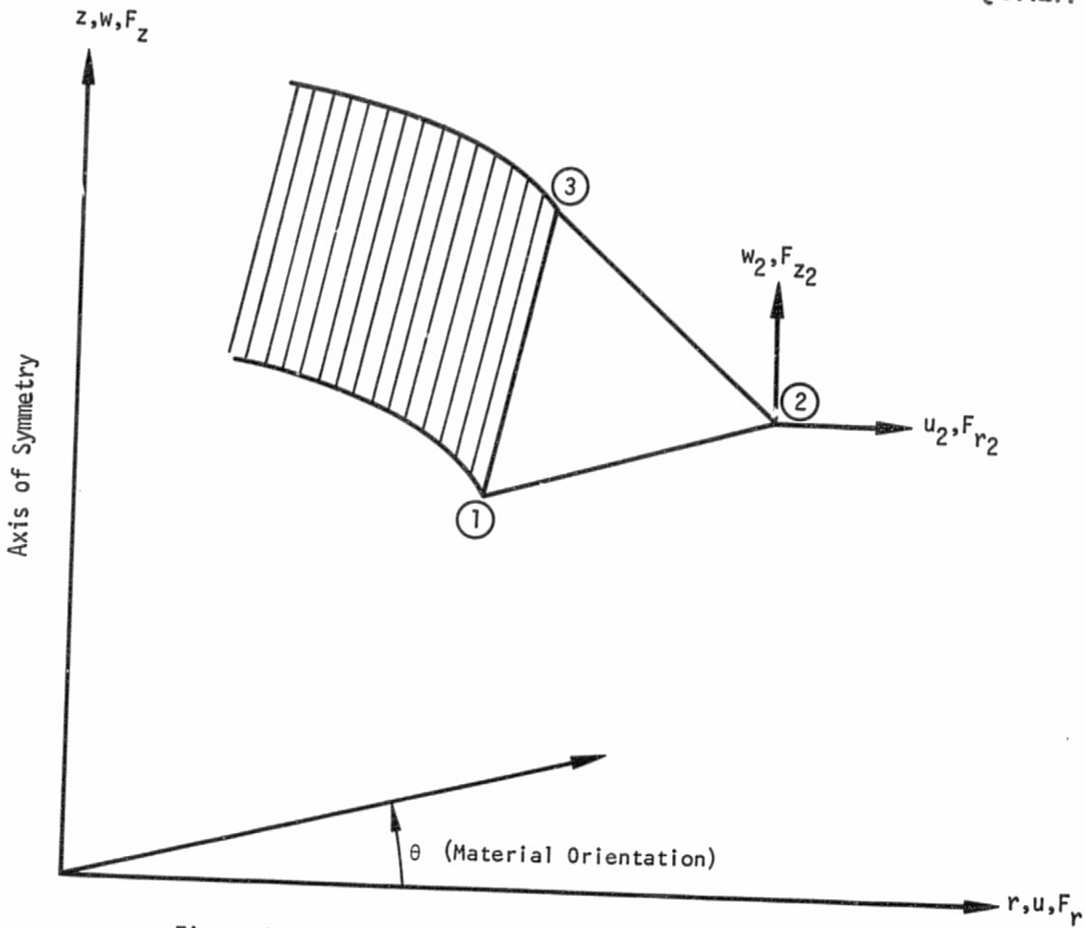


Figure 10. Triangular ring element coordinate system.

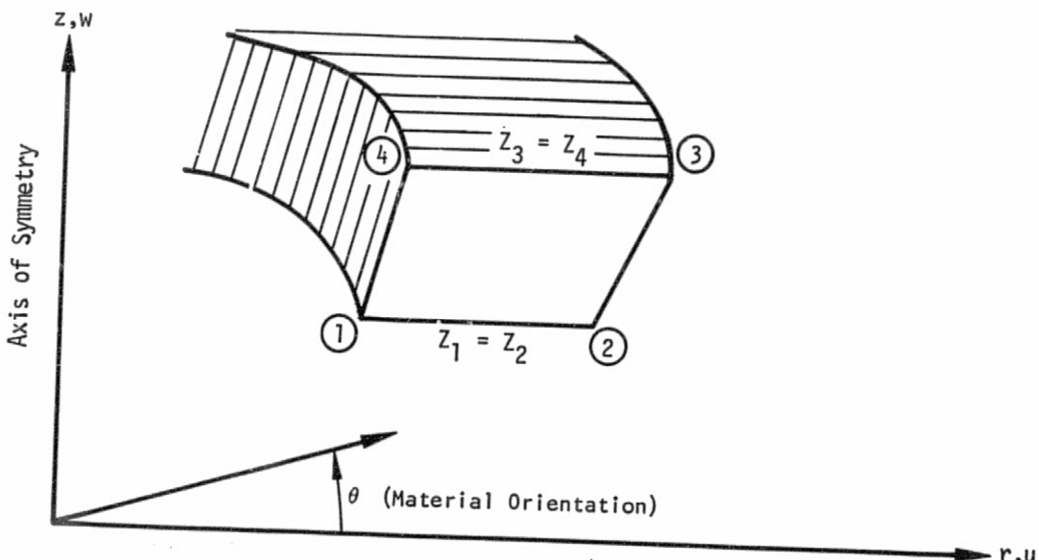
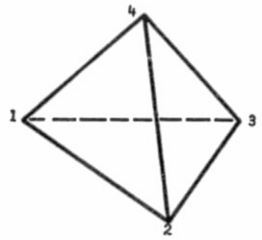
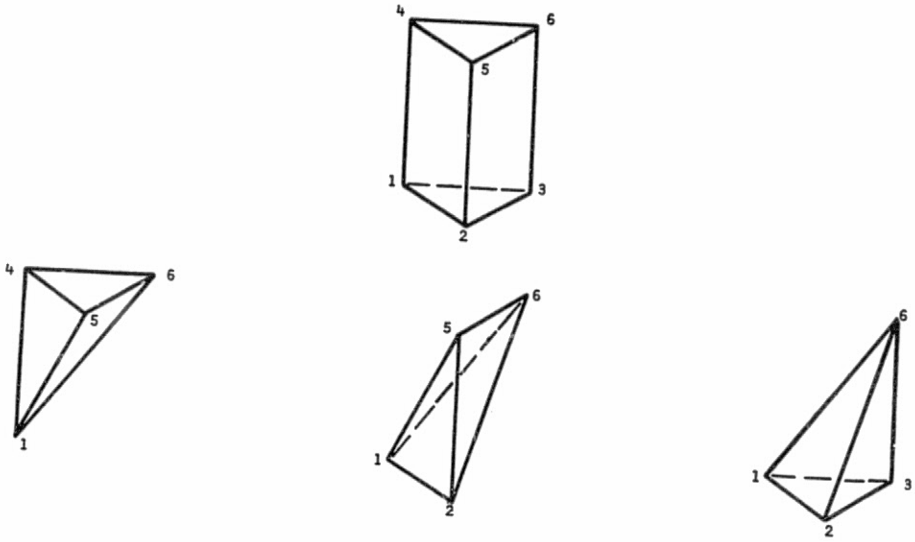


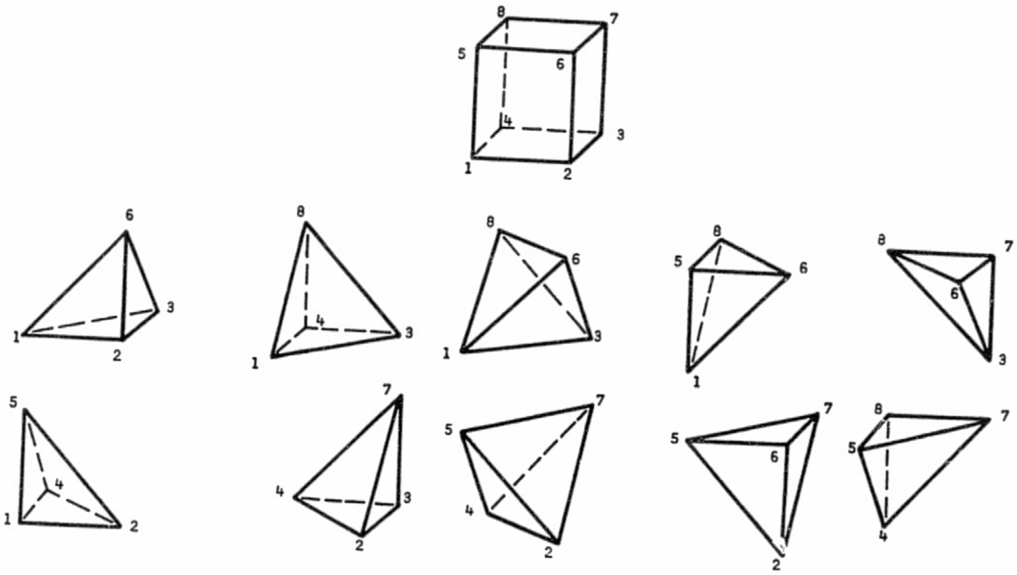
Figure 11. Trapezoidal ring element coordinate system.



(a) Tetrahedron.

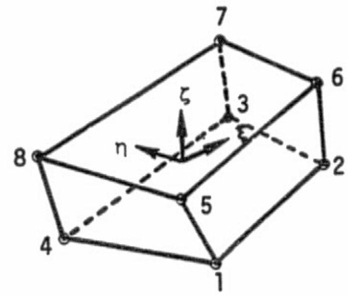


(b) Wedge and One of its Six Decompositions.

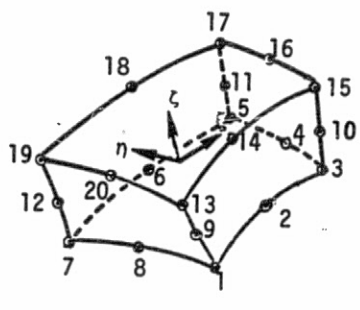


(c) Hexahedron and its Two Decompositions.

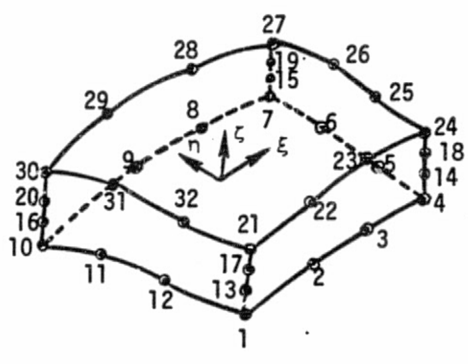
Figure 12. - Polyhedron elements and their subtetrahedra.



(a) Linear



(b) Quadratic



(c) Cubic

Figure 13. Isoparametric solid hexahedron elements

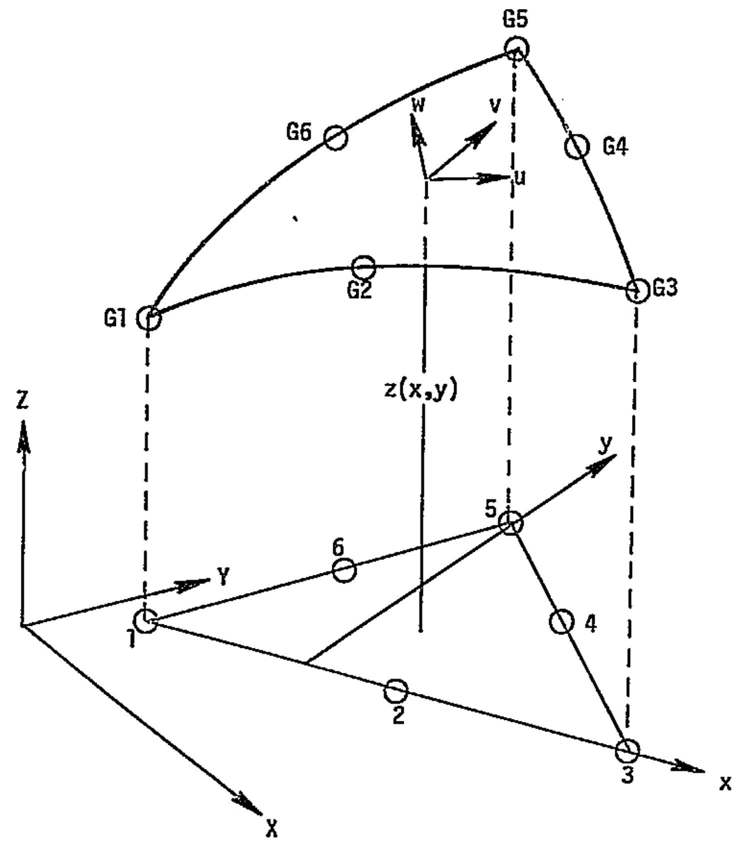


Figure 14. Triangular shallow shell element geometry and coordinate systems.

1.4 CONSTRAINTS AND PARTITIONING

Structural matrices are initially assembled in terms of all structural grid points, which excludes only the extra scalar points introduced for dynamic analysis. These matrices are generated with six degrees of freedom for each geometric grid point and a single degree of freedom for each scalar point. Various constraints are applied to these matrices in order to remove undesired singularities, provide boundary conditions, define rigid elements, and provide other desired characteristics for the structural model.

There are two basic kinds of constraints. Single-point constraints are used to constrain a degree of freedom to zero or to a prescribed value; multipoint constraints and rigid elements are used to constrain one or more degrees of freedom to be equal to linear combinations of the values of other degrees of freedom. The following types of bulk data cards are provided for the definition of constraints:

1. Single-point constraint cards
2. Multipoint constraint cards and rigid element connection cards
3. Cards to define reaction points on free bodies
4. Cards to define the omitted coordinates in matrix partitioning

The latter type does not produce constraint forces in static analysis.

1.4.1 Single-Point Constraints

A single-point constraint applies a fixed value to a translational or rotational component at a geometric grid point or to a scalar point. One of the most common uses of single-point constraints is to specify the boundary conditions of a structural model by fixing the appropriate degrees of freedom. Multiple sets of single-point constraints can be provided in the Bulk Data Deck, with selections made at execution time by using the subcase structure in the Case Control Deck as explained in Section 2.3.3. This procedure is particularly useful in the solution of problems having one or more planes of symmetry.

The elements connected to a grid point may not provide resistance to motion in certain directions, causing the stiffness matrix to be singular. Single-point constraints are used to remove these degrees of freedom from the stiffness matrix. A typical example is a planar structure composed of membrane and extensional elements. The translations normal to the plane and all three rotational degrees of freedom must be constrained since the corresponding stiffness matrix

terms are all zero. If a grid point has a direction of zero stiffness, the single-point constraint need not be exactly in that direction, but only needs to have a component in that direction. This allows the use of single-point constraints for the removal of such singularities regardless of the orientation of the global coordinate system. Although the displacements will depend on the direction of the constraint, the internal forces will be unaffected.

One of the tasks performed by the Structural Matrix Assembler (Section 4.27 of the Programmer's Manual) is to examine the stiffness matrix for singularities at the grid point level. An input NASTRAN card entry STST, to control the tolerance, is available. Singularities remaining at this level, following the application of the single-point constraints, are listed in the Grid Point Singularity Table (GPST). This table is automatically printed following the comparison of the possible singularities tabulated by the Structural Matrix Assembler with the single-point constraints and the dependent coordinates of the multipoint constraint equations provided by the user. The GPST contains all possible combinations of single-point constraints, in the global coordinate system, that can be used to remove the singularities. These remaining singularities are treated only as warnings, because it cannot be determined at the grid point level whether or not the singularities are removed by other means, such as general elements or multipoint constraints in which these singularities are associated with independent coordinates. See the GPSPC module description in Section 5.10 for automatic removal of singularities.

Single-point constraints are defined on SPC, SPC1, SPCADD, and SPCAX cards. The SPC card is the most general way of specifying single-point constraints. The SPC1 card is a less general card that is more convenient when a number of grid points have the same components constrained to a zero displacement. The SPCADD card defines a union of single-point constraint sets specified with SPC or SPC1 cards. The SPCAX card is used only for specifying single-point constraints in problems using conical shell elements.

Single-point constraints can also be defined on the GRID card. In this case, however, the constraints are part of the model and modifications cannot be made at the subcase level. Also, only zero displacements can be specified on the GRID card.

1.4.2 Multipoint Constraints and Rigid Elements

Multipoint constraints and rigid elements are used to constrain one or more degrees of freedom to be equal to linear combinations of the values of other degrees of freedom. In the former case,

the user must explicitly provide the coefficients of the equations. In the latter case, he provides only the connection data and the program internally generates the required coefficients.

1.4.2.1 Multipoint Constraints

Each multipoint constraint is described by a single equation that specifies a linear relationship for two or more degrees of freedom. Multiple sets of multipoint constraints can be provided in the Bulk Data Deck, with selections made at execution time by using the subcase structure in the Case Control Deck as explained in Section 2.3.3. Multipoint constraints are discussed in Sections 3.5.1 and 5.4 of the Theoretical Manual.

Multipoint constraints are defined on MPC, MPCADD and MPCAX cards. The MPC card is the basic card for defining multipoint constraints. The first coordinate mentioned on the card is taken as the dependent degree of freedom, i.e. that degree of freedom that is removed from the equations of motion. Dependent degrees of freedom may appear as independent terms in other equations of the set, however, they may appear as dependent terms in only a single equation. The MPCADD card defines a union of multipoint constraint sets specified with MPC cards. The MPCAX card is used only for specifying multipoint constraints in problems using conical shell elements. Some uses of multipoint constraints are:

1. To enforce zero motion in directions other than those corresponding with components of the global coordinate system. In this case, the multipoint constraint will involve only the degrees of freedom at a single grid point. The constraint equation relates the displacement in the direction of zero motion to the displacement components in the global system at the grid point.
2. To describe rigid elements and mechanisms such as levers, pulleys and gear trains. In this application, the degrees of freedom associated with the rigid element that are in excess of those needed to describe rigid body motion are eliminated with multipoint constraint equations. Treatment of very stiff members as being rigid elements eliminates the ill-conditioning associated with their treatment as ordinary elastic elements.
3. To be used with scalar elements to generate nonstandard structural elements and other special effects.
4. To describe parts of a structure by local vibration modes. This application is treated in section 14.1 of the Theoretical Manual. The general idea is that the matrix of local eigenvectors represents a set of constraints relating physical coordinates to modal coordinates.

The user provides the coefficients in the multipoint constraint equations defined on MPC, MPCADD, and MPCAX cards.

1.4.2.2 Rigid Elements

Rigid elements provide a convenient means of specifying very stiff connections. The user does not provide the required coefficients directly. The program internally generates them from the connection data. Rigid elements are discussed in Section 3.5.6 of the Theoretical Manual.

Rigid elements are defined on CRIGDR, CRIGD1, CRIGD2, and CRIGD3 cards. The CRIGDR card defines a pin-ended rod element that is rigid in extension-compression. The CRIGD1 card defines a rigid element connection in which all six degrees of freedom of each of the dependent grid points are coupled to all six degrees of freedom of the reference grid point. The CRIGD2 card is more general and defines a connection in which selected degrees of freedom of the dependent grid points are coupled to all six degrees of freedom of the reference grid point. The CRIGD3 card is the most general and defines a rigid element in which selected degrees of freedom of the dependent grid points are coupled to six selected degrees of freedom at one or more (up to six) reference grid points.

On all of the rigid element connection cards, the user specifies the degrees of freedom that belong to the dependent set. This specification is implicit on the CRIGD1 card and explicit on the others. It is important to note that a dependent degree of freedom appearing in a rigid element may not appear as dependent in any other rigid element or on a MPC card nor may it be constrained in any other manner. Also, when using the CRIGD3 card, the user must ensure that the six selected degrees of freedom at the reference grid points together are capable of representing any general rigid body motion of the element.

When using several rigid elements and multipoint constraints, the user will often find it useful to turn on DIAG's 21 and 22 in the Executive Control Deck to obtain the GP4 definition of sets of degrees of freedom.

1.4.3 Free Body Supports

In the following discussion, a free body is defined as a structure that is capable of motion without internal stress, i.e., it has one or more rigid body degrees of freedom. The stiffness matrix for a free body is singular with the defect equal to the number of stress-free, or rigid body modes. A solid three-dimensional body has up to six rigid body modes. Linkages and mechanisms can have a greater number. No restriction is placed in the program on the number of stress-free modes, in order to permit the analysis of mechanisms.

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CONSTRAINTS AND PARTITIONING

Free-body supports are defined with a SUPØRT card. In the case of problems using conical shell elements, the SUPAX card is used. In either case, only a single set can be specified, and if such cards appear in the Bulk Data Deck, they are automatically used in the solution. Free-body supports must be defined in the global coordinate system.

In static analysis by the displacement method, the rigid body modes must be restrained in order to remove the singularity of the stiffness matrix. The required constraints may be supplied with single-point constraints, multipoint constraints, or free-body supports. If free-body supports are used, the rigid body characteristics will be calculated and a check will be made on the sufficiency of the supports. Such a check is obtained by calculating the rigid body error ratio as defined in the Rigid Body Matrix Generator operation in Section 3.2.2. This error ratio is automatically printed following the execution of the Rigid Body Matrix Generator. The error ratio should be zero, but may be nonzero for any of the following reasons:

1. Round-off error accumulation
2. Insufficient free-body supports have been provided
3. Redundant free-body supports have been provided

The redundancy of the supports may be caused by improper use of the free-body supports themselves, or by the presence of single-point or multipoint constraints that constrain the rigid body motions.

Static analysis with inertia relief is necessarily made on a model having at least one rigid body motion. Such rigid body motion must be constrained by the use of free-body supports. These supported degrees of freedom define a reference system, and the elastic displacements are calculated relative to the motion of the support points. The element stresses and forces will be independent of any valid set of supports.

Rigid body vibration modes are calculated by a separate procedure provided that a set of free-body supports is supplied by the user. This is done to improve efficiency and, in some cases, reliability. The determinant method, for example, has difficulty extracting zero frequency roots of high multiplicity, whereas the alternate procedure of extracting rigid body modes is both efficient and reliable. If the user does not specify free-body supports (or he specifies an insufficient number of them) the (remaining) rigid body modes will be calculated by the method selected for the finite frequency modes, provided zero frequency is included in the range of interest. If the user does not provide free-body supports, and if zero frequency is not included in the range of interest, the rigid body modes will not be calculated.

Free-body supports must be specified if the mode acceleration method of solution improvement is used for dynamics problems having rigid body degrees of freedom (see Section 9.4 of the Theoretical Manual). This solution improvement technique involves a static solution, and although the dynamic solution can be made on a free-body, the static solution cannot be performed without removing the singularities in the stiffness matrix associated with the rigid body motions.

1.4.4 Partitioning

A two-way partitioning scheme is provided as an optional feature for the NASTRAN model. The partitions are defined by listing the degrees of freedom for one of the partitions on the ØMIT card. These degrees of freedom are referred to as the omitted set. The remaining degrees of freedom are referred to as the analysis set. The ØMIT1 Card is easier to use if a large number of grid points have the same degrees of freedom in the omitted set. The ASET or ASET1 cards can be used to place degrees of freedom in the analysis set with the remaining degrees of freedom being placed in the omitted set. This is easier if the omitted set is large. In the case of problems using conical shell elements, the ØMITAX card is used.

Partitioning can be used to improve the efficiency in the solution of ordinary statics problems where the bandwidth of the unpartitioned stiffness matrix is large enough to cause excessive use of secondary storage devices during the triangular decomposition of the stiffness matrix. In this application, the analysis set should be relatively small and should be selected so that the omitted set will consist of uncoupled partitions, each having a bandwidth of approximately the same size and smaller than the original matrix. The omitted set might be thought of as consisting of several substructures which are coupled to the analysis set.

Matrix partitioning also improves efficiency when solving a number of similar cases with stiffness changes in local regions of the structure. In this application, the omitted set is relatively large, and should be selected so that the structural elements that will be changed are connected only to points in the analysis set. The stiffness matrix for the omitted set is then unaffected by the structural changes, and only the smaller stiffness matrix for the analysis set need be decomposed for each case. In order to avoid repeating the decomposition of the stiffness matrix for the omitted set, the alter feature must be used to replace the functional module SMP1 with SMP2. The alter feature is described in Section 2.2, and a similar use of SMP2 occurs near the end of the DMAP sequence used in the rigid format for Static Analysis with Differential Stiffness.

CONSTRAINTS AND PARTITIONING

One of the more important applications of partitioning is the Guyan Reduction, described in Section 3.5.4 of the Theoretical Manual. This technique is a means for reducing the number of degrees of freedom used in dynamic analysis with minimum loss of accuracy. Its basis is that many fewer grid points are needed to describe the inertia of a structure than are needed to describe its elasticity with comparable accuracy. The error in the approximation is small provided that the set of displacements used for dynamic analysis is judiciously chosen. Its members should be uniformly dispersed throughout the structure and all large mass items should be connected to grid points that are members of the analysis set.

The user is cautioned to consider the fact that the matrix operations associated with this partitioning procedure tend to create nonzero terms and to fill what were previously very sparse matrices. The partitioning option is most effectively used if the members of the omitted set are either a very large fraction or a very small fraction of the total set. In most of the applications the omitted set is a large fraction of the total and the matrices used for analysis, while small, are usually full. If the analysis set is not a small fraction of the total, a solution using the larger, but sparser matrices, may well be more efficient. The partitioning option can also be used to make modest reductions in the order of the problem by placing a few scattered grid points in the omitted set. If the points in the omitted set are uncoupled, the sparseness in the matrices will be well preserved.

1.4.5 The Nested Vector Set Concept Used to Represent Components of Displacement

In constructing the matrices used in the Displacement Approach, each row and/or column of a matrix is associated closely with a grid point, a scalar point or an extra point. Every grid point has 6 degrees of freedom associated with it, and hence 6 rows and/or columns of the matrix. Scalar and extra points only have one degree of freedom. At each point (grid, scalar, extra) these degrees of freedom can be further classified into subsets, depending on the constraints or handling required for particular degrees of freedom. (For example, in a two-dimensional problem, all "z" degrees of freedom are constrained and hence belong to the s (single-point constraint) set). Each degree of freedom can be considered as a "point", and the entire model is the collection of these one-dimensional points.

Nearly all of the matrix operations in displacement analysis are concerned with partitioning, merging, and transforming matrix arrays from one subset of displacement components to another. All the components of displacement of a given type (such as all points constrained by single-point constraints) form a vector set that is distinguished by a subscript from other sets. A given component of displacement can belong to several vector sets. The mutually exclusive vector sets, the sum of whose members are the set of all physical components of displacements, are as follows:

u_m points eliminated by multipoint constraints and rigid elements,

u_s points eliminated by single-point constraints,

u_o points omitted by structural matrix partitioning,

u_r points to which determinate reactions are applied in static analysis,

u_ℓ the remaining structural points used in static analysis (points left over),

u_e extra degrees of freedom introduced in dynamic analysis to describe control systems, etc.

The vector sets obtained by combining two or more of the above sets are (+ sign indicates the union of two sets):

$u_a = u_r + u_\ell$, the set used in real eigenvalue analysis,

$u_d = u_a + u_e$, the set used in dynamic analysis by the direct method,

$u_f = u_a + u_o$, unconstrained (free) structural points,

$u_n = u_f + u_s$, all structural points not constrained by multipoint constraints,

$u_g = u_n + u_m$, all structural (grid) points including scalar points,

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$u_p = u_g + u_e$, all physical points.

In dynamic analysis, additional vector sets are obtained by a modal transformation derived from real eigenvalue analysis of the set u_a. These are:

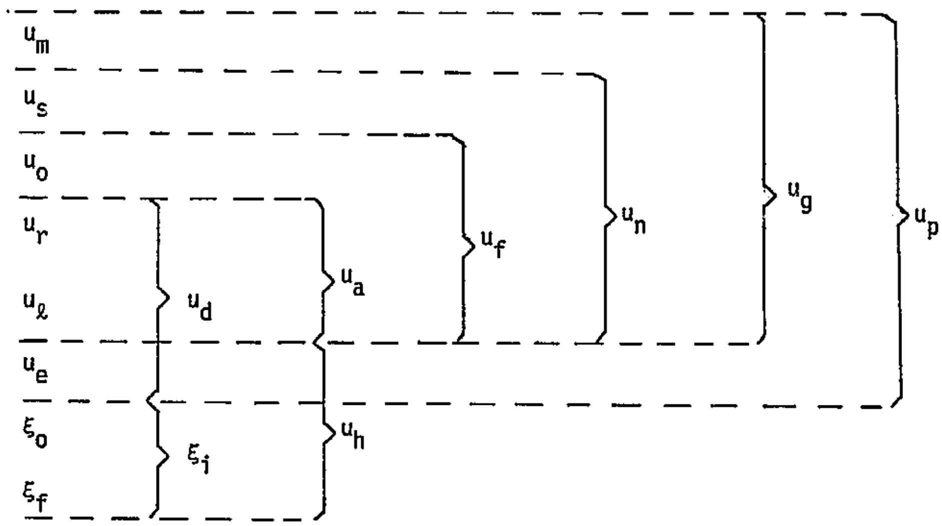
ξ_o rigid body (zero frequency) modal coordinates,

ξ_f finite frequency modal coordinates,

$\xi_i = \xi_o + \xi_f$, the set of all modal coordinates.

One vector set is defined that combines physical and modal coordinates. That set is $u_h = \xi_i + u_e$, the set used in dynamic analysis by the modal method.

The nesting of vector sets is depicted by the following diagram:



The data block USET (USETD in dynamics) is central to this set classification. Each word of USET corresponds to a degree of freedom in the problem. Each set is assigned a bit in the word. If a degree of freedom belongs to a given set, the corresponding bit is on. Every degree of freedom can then be classified by analysis of USET. The common block /BITPØS/ relates the sets to bit numbers. A table indicating the various sets to which each degree of freedom belongs may be obtained by setting DIAG 21 in the Executive Control Deck. This table provides a listing of each grid, scalar, and extra point in the model and shows the assignment of each associated degree of

freedom (six or one) to the sets L, A, F, N, G, R, Ø, S, and M. The S-set is further divided into the SB and SG "sub" sets to indicate constraints applied by SPC cards or GRID cards, respectively. Tables that indicate the membership of A-set, Ø-set, S-set, and M-set may be obtained by setting DIAG 22 in the Executive Control Deck. These tables summarize the degree of freedom assignments for sets M, S, Ø, and A. The S-set is further divided into the SPC and PERM SPC "sub" sets to indicate constraints applied by SPC cards or GRID cards, respectively.

In constructing the matrices used in the Heat Approach, the user must constrain five of the six degrees of freedom associated with each grid point. Since the only unknown at a grid point is its temperature, there is only one degree of freedom per grid point.

In constructing the matrices used in the Aero Approach, the aerodynamic degrees of freedom (including extra points) are added after the structural matrices have been determined. This introduces the following displacement sets:

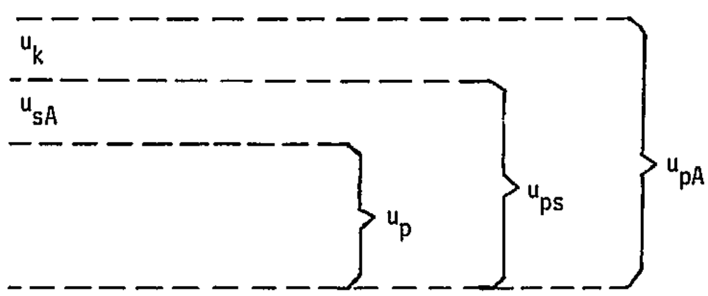
u_k aerodynamic box and body degrees of freedom

u_{sA} permanently constrained degrees of freedom associated with aerodynamic grid points

u_{ps} the union of u_p and u_{sA}

u_{pA} the union of u_k and u_{ps}

The nesting of the vector sets in the Aero Approach is indicated below:



The u_{pA} set replaces the u_p set for output at grid, scalar, and extra points.

1.5 APPLIED LOADS

1.5.1 Static Loads

In NASTRAN, static loads are applied to geometric and scalar grid points in a variety of ways, including:

1. Loads applied directly to grid points.
2. Pressure on surfaces.
3. Gravity loads (internally generated).
4. Centrifugal forces due to steady rotation.
5. Equivalent loads resulting from thermal expansion
6. Equivalent loads resulting from enforced deformations of structural elements.
7. Equivalent loads resulting from enforced displacements of grid points.

Additional information on static loads is given in Section 3.6 of the Theoretical Manual. Any number of load sets can be defined in the Bulk Data Deck. However, only those sets selected in the Case Control Deck, as described in Section 2.3, will be used in the problem solution. The manner of selecting each type of load is specified on the associated bulk data card description in Section 2.4.

The FØRCE card is used to define a static load applied to a geometric grid point in terms of components defined by a local coordinate system. The orientation of the load components depends on the type of local coordinate system used to define the load. The directions of the load components are the same as those indicated on Figure 1 of Section 1.2 for displacement components. The FØRCE1 card is used if the direction is determined by a vector connecting two grid points, and a FØRCE2 card is used if the direction is specified by the cross product of two such vectors. The MØMENT, MØMENT1 and MØMENT2 cards are used in a similar fashion to define the application of a concentrated moment at a geometric grid point. The SLØAD card is used to define a load at a scalar point. In this case, only the magnitude is specified, as only one component of motion exists at a scalar point.

The FØRCEAX and MØMAX cards are used to define the loading of specified harmonics on rings of conical shell elements. FØRCE and MØMENT cards may be used to apply concentrated loads or moments to conical shell elements, providing that such points have been defined with a PØINTAX card.

Pressure loads on triangular and quadrilateral elements are defined with a PLØAD2 card. The positive direction of the loading is determined by the order of the grid points on the element connection card, using the right hand rule. The magnitude and direction of the load is automatically computed from the value of the pressure and the coordinates of the connected grid points. The load is applied to the connected grid points. The PLØAD card is used in a similar fashion to define the loading of any three or four grid points regardless of whether they are connected with two-dimensional elements. The PRESAX card is used to define a pressure loading on a conical shell element.

Pressure loads on the isoparametric solid elements are defined with the PLØAD3 card. The pressure is defined positive outward from the element. The magnitude and direction of the equivalent grid point forces are automatically computed using the isoparametric shape functions of the element to which the load has been applied.

The GRAV card is used to specify a gravity load by providing the components of the gravity vector in any defined coordinate system. The gravity load is obtained from the gravity vector and the mass matrix assembled by the Structural Matrix Assembler (see Section 4.28 of the Programmer's Manual). The gravitational acceleration is not calculated at scalar points. The user is required to introduce gravity loads at scalar points directly.

The RFØRCE card is used to define a static loading condition due to a centrifugal force field. A centrifugal force load is specified by the designation of a grid point that lies on the axis of rotation and by the components of rotational velocity in any defined coordinate system. In the calculation of the centrifugal force, the mass matrix is regarded as pertaining to a set of distinct rigid bodies connected to grid points. Deviations from this viewpoint, such as the use of scalar points or the use of mass coupling between grid points, can result in errors.

Temperatures may be specified for selected elements. The temperatures for a RØD, BAR, CØNRØD or TUBE element are specified on the TEMPRB data card. This card specifies the average temperature on both ends and, in the case of the BAR element, is used to define temperature gradients over the cross section. Temperatures for two dimensional plate and membrane elements are specified on a TEMPP1, TEMPP2, or TEMPP3 data card. The user defined average temperature over the volume is used to produce in-plane loads and stresses. Thermal gradients over the depth of the bending elements, or the resulting moments, may be used to produce bending loads and stresses.

If no thermal element data is given for an element, the temperatures of the connected grid points given on the TEMP, TEMPD or TEMPAX cards are simply averaged to produce an average temperature for the element. The thermal expansion coefficients are defined on the material definition cards. Regardless of the type of thermal data, if the material coefficients for an element are temperature-dependent by use of the MATTi card, they are always calculated from the "average" temperature of the element. The mere presence of a thermal field does not imply the application of a thermal load. A thermal load will not be applied unless the user makes a specific request in the Case Control Deck.

Enforced axial deformations can be applied to rod and bar elements. They are useful in the simulation of misfit and misalignment in engineering structures. As in the case of thermal expansion, the equivalent loads are calculated by separate subroutines for each type of structural element, and are applied to the connected grid points. The magnitude of the axial deformation is specified on a DEFØRM card.

Zero enforced displacements may be specified on GRID, SPC or SPC1 cards. Zero displacements which result in nonzero forces of constraint are usually specified on SPC or SPC1 cards. If GRID cards are used, the constraints become part of the structural model and modifications cannot be made at the subcase level.

Nonzero enforced displacements may be specified on SPC or SPCD cards. The SPC card specifies both the component to be constrained and the magnitude of the enforced displacement. The SPCD card specifies only the magnitude of the enforced displacement. When an SPCD card is used, the component to be constrained must be specified on either an SPC or SPC1 card. The use of the SPCD card avoids

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the decomposition of the stiffness matrix when changes are only made in the magnitudes of the enforced displacements.

The equivalent loads resulting from enforced displacments of grid points are calculated by the program and added to the other applied loads. The magnitudes of the enforced displacements are specified on SPC cards (SPCAX in the case of conical shell problems) in the global coordinate system. The application of the load is automatic when the user selects the associated SPC set in the Case Control Deck.

The LØAD card in the Bulk Data Deck defines a static loading condition that is a linear combination of load sets consisting of loads applied directly to grid points, pressure loads, gravity loads and centrifugal forces. This card must be used if gravity loads are to be used in combination with loads applied directly to grid points, pressure loads or centrifugal forces. The application of the combined loading condition is requested in the Case Control Deck by selecting the set number of the LØAD combination.

It should be noted that the equivalent loads (thermal, enforced deformation and enforced displacement) must have unique set identification numbers and be separately selected in the Case Control Deck. For any particular solution, the total static load will be the sum of the applied loads (grid point loading, pressure loading, gravity loading and centrifugal forces) and the equivalent loads.

1.5.2 Frequency Dependent Loads

A discussion of frequency response calculations is given in Section 12.1 of the Theoretical Manual. The DLØAD card is used to define linear combinations of frequency dependent loads that are defined on RLØAD1 or RLØAD2 cards. The RLØAD1 card defines a frequency dependent load of the form

$$\{P(f)\} = \left\{A[C(f) + iD(f)]e^{i(\theta-2\pi f\tau)}\right\}, \tag{1}$$

where A is defined on a DAREA card, C(f) and D(f) are defined on TABLEDi cards, θ is defined on a DPHASE card and τ is defined on a DELAY card. The RLØAD2 card defines a frequency dependent load of the form

$$\{P(f)\} = \left\{AB(f)e^{i\{\phi(f)+\theta-2\pi f\tau\}}\right\}, \tag{2}$$

where A is defined on a DAREA card, B(f) and $\phi(f)$ are defined on TABLEDi cards, θ is defined on a

DPHASE card, and τ is defined on a DELAY card. The coefficients on the DAREA, DELAY and DPHASE cards may be different for each loaded degree of freedom. The loads are applied to the specified components in the global coordinate system.

A discussion of random response calculations is given in Section 12.2 of the Theoretical Manual. The RANDPS card defines load set power spectral density factors for use in random analysis of the form

$$S_{jk}(f) = (X + iY)G(f) \quad , \tag{3}$$

where G(f) is defined on a TABRNDi card. The subscripts j and k define the subcase numbers of the load definitions. If the applied loads are independent, only the diagonal terms (j=k) need be defined. The RANDT1 card is used to specify the time lag constants for use in the computation of the autocorrelation functions.

1.5.3 Time Dependent Loads

A discussion of transient response calculations is given in Section 11 of the Theoretical Manual. The DLØAD card is used to define linear combinations of time dependent loads that are defined on TLØAD1 and TLØAD2 cards. The TLØAD1 card defines a time dependent load of the form

$$\{P(t)\} = \{AF(t - \tau)\} \quad , \tag{4}$$

where A is defined on a DAREA card, τ is defined on a DELAY card, and $F(t-\tau)$ is defined on a TABLEDi card. The TLØAD2 card defines a time dependent load of the form

$$\{P(t)\} = \begin{cases} \{0\} \, , & \tilde{t} < 0 \text{ or } \tilde{t} > T_2 - T_1 \\ \left\{A\tilde{t}^B e^{C\tilde{t}} \cos(2\pi f\tilde{t}+P)\right\}, & 0 \le \tilde{t} \le T_2 - T_1 \end{cases} \quad , \tag{5}$$

where $\tilde{t} = t - T_1 - \tau$ and A and τ are defined as above. The coefficients on the DAREA and DELAY cards may be different for each loaded degree of freedom. The loads are applied to the specified components in the global coordinate system.

Nonlinear effects are treated as an additional applied load vector, for which the components are functions of either displacements or velocities. This additional load vector is added to the right side of the equations of motion and treated along with the applied load vector during

numerical integration. It is required that the points to which the nonlinear loads are applied and the degrees of freedom on which they depend be members of the solution set, i.e., that they cannot be degrees of freedom eliminated by constraints. It is further required, that if a modal formulation is used, the points referenced by the nonlinear loads be members of the set of extra scalar points introduced for dynamic analysis.

At present, NASTRAN includes four different types of nonlinear elements. For a discussion of nonlinear elements see Section 11.2 of the Theoretical Manual. The NØLIN1 card defines a nonlinear load of the form

$$P_i(t) = S_i T(x_j) \quad , \tag{6}$$

where P_i is the load applied to x_i, S_i is a scale factor, $T(x_j)$ is a tabulated function defined with a TABLEDi card, and x_j is any permissible displacement or velocity component. The NØLIN2 card defines a nonlinear load of the form

$$P_i(t) = S_i \, x_j \, y_k \quad , \tag{7}$$

where x_j and y_k are any permissible pair of displacement or velocity components. They may be the same. The NØLIN3 card defines a nonlinear load of the form

$$P_i(t) = \begin{cases} S_i(x_j)^A & , \quad x_j > 0 \\ 0 & , \quad x_j \le 0 \end{cases} \quad , \tag{8}$$

where A is an exponent. The NØLIN4 card defines a nonlinear load of the form

$$P_i(t) = \begin{cases} -S_i(-x_j)^A & , \quad x_j < 0 \\ 0 & , \quad x_j \ge 0 \end{cases} \quad . \tag{9}$$

Nonlinear loads applied to a massless system without damping will not converge to a steady state solution. Use of DIAG 10 (Section 2.2.1) will cause the nonlinear term $\{N_{n+1}\}$ to be replaced by 1/3 $\{N_{n+1} + N_n + N_{n-1}\}$ where N_{n+1}, N_n and N_{n-1} are the values of the nonlinear loads at time steps preceding the solution time step. Section 11.3 of the Theoretical Manual discusses the integration equations.

1.6 DYNAMIC MATRICES

The dynamic matrices are defined as the stiffness, mass and damping matrices used in either the direct or modal formulation of dynamics problems. The assembly of dynamics matrices is discussed in Section 9.3 of the Theoretical Manual. There are three general sources for the elements of the dynamic matrices.

1. Matrices generated by the Structural Matrix Assembler.
2. Direct input matrices.
3. Modal matrices obtained from real eigenvalue analysis.

The Structural Matrix Assembler generates stiffness terms from the following sources:

1. Structural elements defined on connection cards, e.g., CBAR and CRØD.
2. General elements defined on GENEL cards.
3. Scalar springs defined on CELASi cards.

The Structural Matrix Assembler generates mass terms from the following sources:

1. A 6x6 matrix of mass coefficients at a grid point defined on a CØNM1 card.
2. A concentrated mass element defined on a CØNM2 card in terms of its mass and moments of inertia about its center of gravity.
3. Structural mass for all elements, except plate elements without membrane stiffness, using the mass density on the material definition card.
4. Nonstructural mass for all elements specifying a value on the property card.
5. Scalar masses defined on CMASSi cards.

A discussion of inertia properties, including the Lumped Mass method and the Coupled Mass method are given in Section 5.5 of the Theoretical Manual. The Structural Matrix Assembler will use the Lumped Mass method for bars, rods and plates unless the PARAM card CØUPMASS (see PARAM bulk data card) used to request the Coupled Mass method.

The Structural Matrix Assembler generates damping terms from the following sources:

1. Viscous rod elements defined on CVISC cards.
2. Scalar viscous dampers defined on CDAMPi cards.
3. Element structural damping by multiplying the stiffness matrix of an individual structural element by a damping factor obtained from the material properties (MATi) card for the element.

In addition, uniform structural damping is provided by multiplying the stiffness matrix generated

in Structural Matrix Assembler by a damping factor that is specified by the user on the PARAM card G (see PARAM bulk data card). This form of damping is not recommended for hydroelastic problems.

The direct input matrices are generated by transfer functions (TF cards) or they are supplied directly by the user (DMIG or DMIAX cards). The terms of the direct input matrices may be associated either with grid points or with extra points introduced for dynamic analysis.

The modal matrices are obtained from real eigenvalue analysis using the stiffness and mass matrices generated by the Structural Matrix Assembler.

1.6.1 Direct Formulation

In the direct method of dynamic problem formulation, the degrees of freedom are simply the displacements at grid points. The dynamic matrices are assembled from the direct input matrices and the stiffness, mass and damping matrices generated by the Structural Matrix Assembler. The direct input matrices are generated by transfer functions (TF cards) or they are supplied directly by the user (DMIG or DMIAX cards).

For frequency response analysis and complex eigenvalue analysis the complete dynamic matrices are:

$$[K_{dd}] = (1 + ig)[K^1_{dd}] + [K^2_{dd}] + i[K^4_{dd}], \qquad (1)$$

$$[B_{dd}] = [B^1_{dd}] + [B^2_{dd}] \quad , \qquad (2)$$

$$[M_{dd}] = [M^1_{dd}] + [M^2_{dd}] \quad , \qquad (3)$$

where the subscripts dd indicate the solution set composed of the degrees of freedom remaining after all constraints have been applied and the extra scalar points introduced for dynamic analysis. The matrices K, B and M are the stiffness, damping and mass matrices respectively. The superscript 1 indicates the matrices generated by the Structural Matrix Assembler. The superscript 2 indicates the direct input matrices. The matrix $[K^4_{dd}]$ is a structural damping matrix obtained by multiplying the stiffness matrix of an individual structural element by a damping factor obtained from the material properties (MATi) card for the element. The matrix $[K^1_{dd}]$ is multiplied by the damping factor (g) to provide for uniform structural damping in cases where it is appropriate. The constant g is specified by the user on a PARAM card (see PARAM bulk data card).

For transient response analysis the complete dynamic matrices are:

$$[K_{dd}] = [K^1_{dd}] + [K^2_{dd}] \quad , \tag{4}$$

$$[B_{dd}] = [B^1_{dd}] + [B^2_{dd}] + \frac{g}{\omega_3}[K^1_{dd}] + \frac{1}{\omega_4}[K^4_{dd}] \quad , \tag{5}$$

$$[M_{dd}] = [M^1_{dd}] + [M^2_{dd}] \quad , \tag{6}$$

where ω_3 is the radian frequency at which the term $\frac{g}{\omega_3}[K^1_{dd}]$ produces the same magnitude of damping as the term $ig[K^1_{dd}]$ in frequency response analysis, and ω_4 is the radian frequency at which the term $\frac{1}{\omega_4}[K^4_{dd}]$ produces the same magnitude of damping as the term $i[K^4_{dd}]$ in frequency response analysis. The equivalent viscous damping is only an approximation to the structural damping as the viscous damping forces are larger at higher frequencies and smaller at lower frequencies. Therefore, the quantities ω_3 and ω_4 are frequently selected by the user to be at the center of the frequency range of interest. A small value of g/ω_3 is frequently useful to insure stability of higher modes in nonlinear transient analysis. The user specifies the values of ω_3 and ω_4 on PARAM cards W3 and W4 (see PARAM bulk data card). If ω_3 and ω_4 are omitted, the corresponding terms are ignored.

1.6.2 Modal Formulation

In the modal method of dynamic problem formulation, the vibration modes of the structure in a selected frequency range are used as degrees of freedom, thereby reducing the number of degrees of freedom while maintaining accuracy in the selected frequency range. The frequency range is specified on PARAM cards by either selecting the number of lowest modes obtained from a real eigenvalue analysis or selecting all of the modes in a given frequency range (see PARAM bulk data card).

It is important to have both direct and modal methods of dynamic problem formulation, in order to maximize efficiency in different situations. The modal method will usually be more efficient in problems where a small fraction of all of the modes are sufficient to produce the desired accuracy, provided that the bandwidth of the direct stiffness matrix is large. The bandwidth may be large due either to a compact structural arrangement or to dynamic coupling effects. The direct method will usually be more efficient for problems in which the bandwidth of the direct stiffness matrix is small and for problems with dynamic coupling in which a large

fraction of the vibration modes are required to produce the desired accuracy. For problems without dynamic coupling, i.e., for problems in which the matrices of the modal formulation are diagonal, the modal method will frequently be more efficient, even though a large fraction of the modes are needed.

The complete dynamic matrices used in dynamic analysis by the modal method include the direct input mass, damping and stiffness matrices $[M^2_{dd}]$, $[B^2_{dd}]$, $[K^2_{dd}]$, and the modal matrices $[m_i]$, $[b_i]$ and $[k_i]$, obtained from real eigenvalue analysis. The matrix $[m_i]$ is the modal mass matrix with off-diagonal terms (which should be zero) omitted. The modal damping matrix $[b_i]$ and stiffness matrix $[k_i]$ are obtained from $[m_i]$ by:

$$[b_i] = [2\pi f_i \; g(f_i) \; m_i] \quad , \tag{7}$$

$$[k_i] = [4\pi^2 \; f_i^2 \; m_i] \quad , \tag{8}$$

where f_i is the frequency of the i^{th} normal mode and $g(f_i)$ is obtained by interpolation of a table supplied by the user to represent the variation of structural damping with frequency. This table is defined with a TABDMP1 card. Structural damping will not be used in the modal formulation unless an SDAMPING card is used in the Case Control Deck to select a particular TABDMP1 card. The specification of damping properties for the modal method is somewhat less general than it is for the direct method, in that viscous dampers and nonuniform structural damping are not used.

The mode acceleration method of data recovery is optional when using the modal formulation for transient response and frequency response problems, see Section 9.4 of the Theoretical Manual for details. In this procedure, the inertia and damping forces are computed from the modal solution. These forces are then added to the applied forces and the combination is used to obtain a more accurate displacement vector for the structure by static analysis. This improved displacement vector is used in the stress recovery operation. The mode acceleration method is selected with the PARAM card MØDACC (see PARAM bulk data card).

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1.7 HYDROELASTIC MODELING

There are two methods of hydroelastic modeling currently available in NASTRAN. One is the axisymmetric hydroelastic modeling capability and the other is the three-dimensional hydroelastic modeling capability. These are described in Sections 1.7.1 and 1.7.2, respectively.

The NASTRAN axisymmetric hydroelastic modeling capability is designed primarily for the solution of problems involving small motion dynamic response of models with combined structure and fluid effects. The options include both rigid and flexible container boundaries, free surface effects and compressibility. The fluid is described by axisymmetric finite elements. The structure is described by conventional nonaxisymmetric elements to form matching boundaries with the fluid.

The NASTRAN three-dimensional hydroelastic modeling capability is designed for the solution of problems involving interacting, arbitrarily-shaped structures and fluids, including tilted free surfaces, and allows for more efficient methods of obtaining solutions for large-order problems. The fluid is modeled by three-dimensional solid elements with options for tetrahedron, wedge and hexahedron shapes. The elements are connected to fluid grid points which define the pressure in the fluid at specified locations. The structure may be modeled arbitrarily using conventional NASTRAN elements. The fluids are assumed to be incompressible, irrotational, and non-viscous.

1.7.1 Axisymmetric Hydroelastic Modeling

1.7.1.1 Solution of the NASTRAN Fluid Model

The NASTRAN axisymmetric hydroelastic option allows the user to solve a wide variety of fluid problems having structural interfaces, compressibility and gravity effects. A complete derivation of the NASTRAN model and an explanation of the assumptions are given in Section 16.1 of the Theoretical Manual. The input data and the solution logic have many similarities to a structural model. The standard normal modes analysis, transient analysis, complex eigenvalue analysis and frequency response solutions are available with minor restrictions. The differences between a NASTRAN fluid model and an ordinary structural problem are due to the physical properties of a fluid and are summarized below:

1. The independent degrees of freedom for a fluid are the Fourier coefficients of the pressure function (i.e. "harmonic pressures") in an axisymmetric coordinate system. The independent degrees of freedom for a structure are typically displacements and rotations at a physical point in space.
2. Much like the structural model, the fluid data will produce "stiffness" and "mass" matrices. Because they now relate pressures and flow instead of displacements and forces, their physical meaning is quite different. The user may not apply loads, constraints, sequencing or omitted coordinates "directly" on the fluid points involved. Instead, the user supplies information related to the boundaries and NASTRAN internally generates the correct constraints, sequencing and matrix terms. Indirect methods, however, are available to the user for utilizing the internally generated points as normal grid or scalar points. See Section 1.7.1.4 for the identification code.
3. When a physical structure is to be connected to the fluid, the user supplies a list of fluid points and a related list of special structural grid points. NASTRAN will produce unsymmetric matrix terms which define the actual physical relations. A special provision is included in NASTRAN in the event that the structure has planes of symmetry. The user may, if he wishes, define only a section of the boundary and solve his problem with symmetric or antisymmetric constraints. The fluid-structure interface will take the missing sections of structural boundary into account.
4. Because of the special nature of the fluid problems, various user convenience options are absent. The fluid elements and harmonic pressures may not be included in the structural plots at present. Plotting the harmonic pressures versus frequency or time may not be

"directly" requested. Because mass matrix terms are automatically generated if compressibility or free surface effects are present, the weight and center of gravity calculations with fluid elements present may not be correct and should be avoided. Also, the inertia relief rigid format uses the mass matrix to produce internal loads and if fluids are included, these special fluid terms in the mass matrix may produce erroneous results.

In spite of the numerous differences between a NASTRAN structural model and a NASTRAN fluid model, the similarities allow the user to formulate a model with a minimum of data preparation and obtain efficient solutions to large order problems. The similarities of the fluid model to the NASTRAN structural model are as follows:

1. The fluid is described by points in space and finite element connections. The locations of the axisymmetric fluid points are described by rings (RINGFL) about a polar axis, much like the axisymmetric conical shell. The rings are connected by elements (CFLUIDi) which have the properties of density and bulk modulus of compressibility. Each fluid ring produces, internally, a series of NASTRAN scalar points, P^n and P^{n*} (i.e. "harmonic pressures"), describing the pressure function, $P(\phi)$, in the following equation:

$$P(\phi) = P^{o} + \sum_{n=1}^{N} P^{n} \cos n\phi + \sum_{n=1}^{N} P^{n*} \sin n\phi \qquad 0 < N < 100$$

   where the set of harmonics 0, n and n* are selected by the user. If the user desires the output of pressure at specific points on the circular ring, he may specify them as "pressure points" (PRESPT) by giving a point number and an angle on a specified fluid ring. The output data will have the values of pressure at the angle, ϕ, given in the above equation. The output of free surface displacements normal to the surface (FREEPT) are also available at specified angles, ϕ. The Case Control card option "AXISYM=FLUID" is necessary when any harmonic fluid degrees of freedom are included.

2. The input data to NASTRAN may include all of the existing options exrept the axisymmetric structural element data. All of the existing Case Control options may be included with some additional fluid Case Control requests. All of the structural element and constraint data may be used (but not connected to RINGFL, PRESPT or FREEPT fluid points). The structure-fluid boundary is defined with the aid of special grid points (GRIDB) which may be used for any purpose that a structural grid point is presently used.

3. The output data options for the structural part of a hydroelastic model are unchanged from the existing NASTRAN options. The output values for the fluid will be produced in the same form as the displacement vectors, but with format modifications for the harmonic data. Printed values for the fluid may include both real and complex values. Pressures and free surface displacements, and their velocities and accelerations, may be printed with the same request (the Case Control request PRESSURE=SET is equivalent to DISP=SET) as structural displacements, velocities and accelerations. Structural plots are restricted to GRID and GRIDB points and any elements connected to them. X-Y plot and Random Analysis capabilities are available for FREEPT and PRESPT points if they are treated as scalar points. The RINGFL point identification numbers may not be used in any plot request, instead the special internally generated points used for harmonics may be requested in X-Y plots and Random Analysis. See Section 1.7.1.4 for the identification number code. No element stress or force data is produced for the fluid elements. As in the axisymmetric conical shell problem, the Case Control request HARMØNICS=N is used to select up to the Nth harmonic for output.

1.7.1.2 Hydroelastic Input Data

A number of special NASTRAN data cards are required for fluid analysis problems. These cards are compatible with structural NASTRAN data. A brief description of the uses for each bulk data card follows.

AXIF

This card controls the formulation of the axisymmetric fluid problem. It is a required card if any of the subsequent fluid-related cards are present. The data references a fluid-related coordinate system to define the axis of symmetry. The gravity parameter is included on the card rather than on the GRAV card because the direction of gravity must be parallel to the axis of symmetry. The values of density and bulk elastic modulus are conveniences in the event that these properties are constant throughtout the fluid. A list of harmonics and the request for the nonsymmetric (sine) coefficients are included on this card to allow the user to select any of the harmonics without producing extra matrix terms for the missing harmonics. A change in this list, however, will require a restart at the beginning of the problem.

RINGFL

The geometry of the fluid model about the axis of symmetry is defined with the aid of these data cards. The RINGFL data cards serve somewhat the same function for the fluid as the GRID cards serve in the structural model. In fact, each RINGFL card will produce, internally, a special grid point for each of the various harmonics selected on the AXIF data card. They may not, however, be connected directly to normal NASTRAN structural elements (see GRIDB and BDYLIST data cards). No constraints may be applied directly to RINGFL fluid points.

CFLUIDi

The data on these cards are used to define a volume of fluid bounded by the referenced RINGFL points. The volume is called an element and logically serves the same purpose as a structural finite element. The physical properties (density and bulk modulus) of the fluid element may be defined on this card if they are variables with respect to the geometry. If a property is not defined, the default value on the AXIF card is assumed. Two connected circles (RINGFL) must be used to define fluid elements adjacent to the axis of symmetry. A choice of three or four points is available in the remainder of the fluid.

GRIDB

This card provides an alternative to the GRID card for the definition of structural grid points. It also identifies the structural grid point with a particular RINGFL fluid point for hydroelastic problems. The particular purpose for this card is to force the user to place structural boundary points in exactly the same locations as the fluid points on the boundary. The format of the GRIDB card is identical to the format of the GRID card except that one additional field is used to identify the RINGFL point. The GRDSET card, however, is not used for GRIDB data.

If the user desires, he may use GRIDB cards without a fluid model. This is convenient in case the user wishes to solve his structural problem first and to add the fluid effects later without converting GRID cards to GRIDB cards. The referenced RINGFL point must still be included in a boundary list (BDYLIST), see below, and the AXIF card must always be present when GRIDB cards are used. (The fluid effects are eliminated by specifying no harmonics.)

FREEPT, PRESPT

These cards are used to define points on a free surface for surface displacement output and points in the fluid for pressure output. No constraints may be applied to these points. Scalar elements and direct matrix data may be connected to these points, but the physical meaning of the elements will be different from that in the structural case.

FSLIST, BDYLIST

The purpose for these cards is to allow the user to define the boundaries of the fluid with complete freedom of choice. The FSLIST card defines a list of fluid points which lie on a free surface. The BDYLIST data is a list of fluid points to which structural GRIDB points are connected. Points on the boundary of the fluid for which BDYLIST or FSLIST data are not defined are assumed to be rigidly restrained from motion in a direction normal to the surface.

With both of these lists the sequence of the listed points determines the nature of the boundary. The following directions will aid the user in producing a list.

1. Draw the z axis upward and the r axis to the right. Plot the locations of the fluid points on the right hand side of z.
2. If one imagines oneself traveling along the free surface or boundary with the fluid on one's right side, the sequence of points encountered is used for the list. If the surface or boundary touches the axis, the word "AXIS" is placed in the list. "AXIS" may be used only for the first and/or last point in the list.
3. The free surface must be consistent with static equilibrium. With no gravity field, any free surface consistent with axial symmetry is allowed. With gravity, the free surface must be a plane perpendicular to the z axis of the fluid coordinate system.
4. Multiple free surface lists and boundary lists are allowed. A fluid point may be included in any number of lists.

FLSYM

This card allows the user to optionally model a portion of the structure with planes of symmetry containing the polar axis of the fluid. The first plane of symmetry is assumed at $\phi = 0.0$ and the second plane of symmetry is assumed at $\phi = 360°/M$ where M is an integer specified on the card. Also specified are the types of symmetry for each plane, symmetric (S) or antisymmetric (A).

The user must also supply the relevant constraint data for the structure. The solution is performed correctly only for those harmonic coefficients that are compatible with the symmetry conditions as illustrated in the following example for quarter symmetry, M = 4.

Series	Plane 1	Plane 2	
		S	A
Cosine	S	0,2,4,...	1,3,5,...
	A	none	none
Sine (*)	S	none	none
	A	1,3,5,...	2,4,6,...

DMIAX

These cards are used for Direct Matrix Input for special purposes such as surface friction effects. They are equivalent to the DMIG cards, the only difference being the capability to specify the harmonic numbers for the degrees of freedom. A matrix may be defined with either DMIG or DMIAX cards, but not with both.

1.7.1.3 Rigid Formats

The characteristics of the fluid analysis problems which cause restrictions on the type of solution are:

1. The fluid-structure interface is mathematically described by a set of unsymmetric matrices. Since the first six Rigid Formats are restricted to the use of symmetric matrices, the fluid-structure boundary is ignored. Thus, for any of these Rigid Formats, the program solves the problem for a fluid in a rigid container with an optional free surface and an uncoupled elastic structure with no fluid present.
2. No means are provided for the direct input of applied loads on the fluid. The only direct means of exciting the fluid is through the structure-fluid boundary. The fluid problem may be formulated in any rigid format. However, only some will provide nontrivial solutions.

The suggested Rigid Formats for the axisymmetric fluid and the restrictions on each are described below:

Rigid Format No. 3 - Normal Modes Analysis

The modes of a fluid in a rigid container may be extracted with a conventional solution request. Free surface effects with or without gravity may be accounted for. Any structure data in the deck will be treated as a disjoint problem. (The structure may also produce normal modes.) Normalization of the eigenvectors using the PØINT option will cause a fatal error.

Rigid Format No. 7 - Direct Complex Eigenvalue Analysis

The coupled modes of the fluid and structure must be solved with this rigid format. If no damping or direct input matrices are added, the resulting complex roots will be purely imaginary numbers, whose values are the natural frequencies of the system. The mode shape of the combination may be normalized to the maximum quantity (harmonic pressure or structural displacement) or to a specified structural point displacement.

Rigid Format No. 8 - Direct Frequency and Random Response

This solution may be used directly if the loads are applied only to the structural points. The use of overall structural damping (parameter g) is not recommended since the fluid matrices will be affected incorrectly. Output restrictions are listed in Section 1.7.1.1.

Rigid Format No. 9 - Direct Transient Response

Transient analysis may be performed directly on the fluid-structure system if the following rules apply.

1. Applied loads and initial conditions are only given to the structural points.
2. All quantities are measured relative to static equilibrium. The initial values of the pressures are assumed to be at equilibrium.
3. Overall structural damping (parameters ω_3 and g) must not be used.
4. Output restrictions are listed in Section 1.7.1.1.

Rigid Formats 10, 11 and 12 - Modal Formulations

Although these rigid formats may be used in a fluid dynamics problem, their practicality is limited. The modal coordinates used to formulate the dynamic matrices will be the normal modes of both the fluid and the structure solved as uncoupled systems. Even though the range of natural frequencies would be typically very different for the fluid from that for the structure, NASTRAN will select both sets of modes from a given fixed frequency range. The safest method with the present system is the extraction of all modes for both systems with the Tridiagonalization Method. This procedure, however, results in a dynamic system with large full matrices. Direct formulation would be more efficient in that case. At present, the capability for fluid-structure boundary coupling is not provided with Rigid Formats 10, 11 and 12. However, the capability may be provided by means of an ALTER using the same logic as in the direct formulations.

1.7.1.4 Hydroelastic Data Processing

The fluid related data cards submitted by the user are processed by the NASTRAN Preface to produce equivalent grid point, scalar point, element connection and constraint data card images. Each specified harmonic, N, of the Fourier series solution produces a complete set of special grid and connection card images. In order to retain unique internal identification numbers for each harmonic, the user (or external) identification numbers are encoded by the algorithm below:

RINGFL points:

NASTRAN (or internal) grid ID = User (or external) ring ID + 1,000,000 x I_N

where

I_N = N + 1 cosine series

I_N = N + 1/2 sine series

CFLUIDi connection cards:

NASTRAN (or internal) element ID = User (or external) element ID x 1000 + I_N

where I_N is defined above for each harmonic N.

For example, if the user requested all harmonics from zero to two, including the sine(*) series, each RINGFL card will produce five special grid cards internally. If the user's

Identification number (in field 2 of the RINGFL data card) were 37, the internally generated grid points would have the following identification numbers:

Harmonic	ID
0	1,000,037
1*	1,500,037
1	2,000,037
2*	2,500,037
2	3,000,037

These equivalent grid points are resequenced automatically by NASTRAN to be adjacent to the original RINGFL identification number. A RINGFL point may not be resequenced by the user.

The output from matrix printout, table printout, and error messages will have the fluid points labeled in this form. If the user wishes, he may use these numbers as scalar points for Random Analysis, X-Y plotting, or for any other purpose.

In addition to the multiple sets of points and connection cards, the NASTRAN Preface also may generate constraint sets. For example, if a free surface (FSLIST) is specified in a zero-gravity field, the pressures are constrained by NASTRAN to zero. For this case, the internally generated set of single point constraints are internally combined with any user defined structural constraints and will always be automatically selected.

If pressures at points in the fluid (PRESPT) or gravity dependent normal displacements on the free surface (FREEPT) are requested, the program will convert them to scalar points and create a set of multipoint constraints with the scalar points as dependent variables. The constraint set will be internally combined with any user defined sets and will be selected automatically.

The PRESPT and FREEPT scalar points may be used as normal scalar points for purposes such as plotting versus frequency or time. Although the FREEPT values are displacements, scalar elements connected to them will have a different meaning from that in the structural case.

1.7.2 Three-Dimensional Hydroelastic Modeling

1.7.2.1 Solution Approach

The three-dimensional hydroelasticity capability in NASTRAN allows for the solution of problems involving interacting, arbitrarily-shaped structures and fluids. It is intended for the vibration analysis of fluid-filled tanks in an acceleration field where the fluid motions interact with the structure displacements. Both free surface sloshing modes and higher frequency coupled modes may be obtained from the analysis.

The method used to formulate the fluid/structure equations is described in Reference 1. The basis for defining the fluid is three-dimensional finite elements connected to fluid grid points defining the Eulerian pressure at a point fixed in space. The use of a single degree-of-freedom pressure at each point rather than three displacements allows a finer mesh of elements with a reasonable matrix order.

In the formulation of the fluid/structure system, the interior fluid degrees of freedom are transformed and removed from the solution matrices. The eigenvalues of the combination are extracted from small, fully dense, symmetric mass and stiffness matrices, efficiently processed with the "Givens" method. The solution matrices are defined only by the free surface displacements and the reduced structure coordinates.

All NASTRAN modeling options are available for the definition of the structure. All options for the Executive Control and Case Control data for normal modes analysis are also available for the hydroelastic problems. In addition to the normal NASTRAN data, a hydroelastic problem requires the addition of a finite element fluid model, the specification of its boundaries and the addition of special control data.

For three-dimensional hydroelastic analysis, the fluid is modeled with three-dimensional finite elements having shapes defined by tetrahedra (CFTETRA), wedge (CFWEDGE) and hexagonal (CFHEX1 or CFHEX2) volumes. The fluid is assumed to be locally incompressible and non-viscous with small motions relative to the overall free body displacements of the system. The following options are provided for defining the fluid boundary conditions.

1. The default boundary is a rigid wall.
2. Pure free surfaces are defined with single point constraints.
3. Free surfaces with gravity effects are specified with CFFREE data cards.
4. Fluid/structure boundaries are defined by CFLSTR data cards.

Several alternate paths are available for the execution of the problem and the formulation of the solution equations. These are:

1. Direct versus Modal Structure Formulation

   In "direct" formulation, the solution matrices are defined by the structure degrees of freedom (after constrained and omitted points are removed) plus one degree of freedom for each free surface point defined on CFFREE data. The alternate "modal" formulation calculates the modes of the empty structure and uses the generalized displacements of these modes with the free surface degrees of freedom in the solution matrix formulation. Although the modal formulation requires the additional cost of another eigenvalue extraction process, the combination system matrices will be smaller. This method is recommended for problems where several different fluid models are used with the same structure model. The structure modes need only be calculated once. Different fluid models may be analyzed using the NASTRAN restart procedure to recover the structure mode data.

2. Compressibility Options

   Two methods are provided for defining the compressible fluid effects. The overall compressibility of the enclosed volume may be specified as a parametric number which, in effect, provides a stiffness factor applied to the total volume change. The alternate method produces zero volume change by automatically constraining one degree of freedom in the system. The latter method is not allowed in the "modal" formulation option.

3. Differential Stiffness Effects (Ullage Pressure)

   An option has been provided for including the effects of ullage pressure on the structure stiffness. These additional stiffness terms are calculated in a separate structure-only Rigid Format 4 analysis with pressures defined by static loads. The differential stiffness is transferred to the problem with the NASTRAN checkpoint/restart procedure and is controlled by two parameters, DISTIF and DIFSCALE.

In the following sections, the actual NASTRAN input is described. The section on the Executive Control Deck describes the overall system control and the available parametric data. The section on the Case Control Deck describes the control of optional input cases and output requests. The Bulk Data Deck section describes the detailed formats for each bulk data card.

1.7.2.2 Executive Control Deck

The hydroelastic Executive Control Deck is similar to that for the standard normal modes analysis, Rigid Format 3. When running the hydroelastic analyses, the user must insert one of the special DMAP ALTER packages into his Executive Control Deck. These ALTER packages are delivered with the NASTRAN system.

Two special DIAGs are provided for the hydroelastic analysis.

DIAG 32 - Prints a list of degrees of freedom including fluid point definitions. For each point, an indication is made identifying the sets to which it belongs.

DIAG 33 - Prints the contents of selected displacement sets. For each set, a list of all degrees of freedom belonging to the set is given.

These two DIAGs produce output similar to that provided by DIAGs 21 and 22 except that the following hydroelastic sets are included or modified:

Ux = Structure point

Uy = Fluid point

Ufr = Free surface point

Uz = Ux + Ufr

Uab = a bits (structure only)

Ui = Interior fluid points

Ua = Uab + Ufr

<u>Hydroelastic DMAP ALTERs</u>

Two sets of DMAP ALTERs to Rigid Format 3 are provided to perform the three-dimensional hydroelastic analysis. The ALTERs obtain the hydroelastic solution with either direct or modal formulation.

Several optional parameters may be specified by the user for each type of formulation. These parameters are all described in Section 1.7.2.4 under the description of the hydroelastic Bulk Data Deck.

1.7.2.3 Case Control Deck

The Case Control data for normal modes analysis, Rigid Format 3, is not modified for direct hydroelastic solutions. For modal formulation, the data is similar except that two sets of subcases must be provided. The first set must select an EIGR card (by means of the METHØD card) to

define eigenvalue extraction for the structure-only model. Several subcases may be used to define output requests for different vectors with the MØDES card. A second set of subcases is also needed to define eigenvalue extraction and output requests for the combined fluid/structure model. If the NEWMØDE or ØLDSTR parameter is used with modal formulation, only the second set of subcases, used for the complete model, is required. Three sample Case Control Decks are shown below.

Direct Formulation:

```
TITLE =
SPC = 10
METHØD = 50
DISP = ALL
```

Modal Formulation:

```
TITLE =
SPC = 10
SUBCASE 1
    LABEL = MØDES OF EMPTY STRUCTURE
    METHØD = 10
    DISP = NØNE
SUBCASE 2
    LABEL = MØDES WITH FLUID INCLUDED
    METHØD = 20
    DISP = ALL
```

Modal Formulation with Selective Output Requests:

```
TITLE =
SPC = 10
SUBCASE 1
    LABEL = STRUCTURE MØDES 1 & 2
    METHØD = 10
    DISP = ALL
    MØDES = 2
```

```
SUBCASE 3
    LABEL = STRUCTURE MØDES 3 & 4
    DISP = NØNE
SUBCASE 5
    LABEL = FLUID/STRUCTURE MØDES 1-3
    METHØD = 20
    DISP = ALL
    MØDES = 3
SUBCASE 8
    LABEL = FLUID/STRUCTURE MØDE 4
    DISP = NØNE
```

In the third and last example above, the eigenvectors for only the first two structure modes and the first three combined modes will be printed.

<u>Hydroelastic Output Control</u>

The structure printout and plotting Case Control requests are used to control both the fluid and structure outputs. The following data is available:

1. Structure-related data such as displacements, forces and stresses are processed with normal NASTRAN control.
2. Fluid internal pressures are output by including their grid point identification numbers in the DISP = output request. If the fluid point is on a free surface defined by CFFREE data, the actual free surface displacements will be printed.
3. Both structure and fluid elements may be plotted as undeformed shapes. The interior fluid point degrees of freedom are actually pressures and should not be plotted as deformed shapes.
4. The deformed shape of the free surface may be plotted using the "SHAPE" or "VECTØR" plot options. It is recommended that PLØTEL elements be used to define the free surface. If the fluid elements CFHEX1, CFHEX2, etc., are used in the requested plot set, all of their boundaries will be plotted and will result in a confused plot.
5. The use of the MØDES card to control output requests is described under the Case Control Deck section.

1.7.2.4 Bulk Data Deck

The bulk data cards that pertain specifically to three-dimensional hydroelastic modeling are: CFFREE, CFHEXi (i = 1 or 2), CFLSTR, CFTETRA, CFWEDGE and MATF. These are all described in Section 2.4 along with all other NASTRAN bulk data cards. These cards are used to define the fluid and fluid/structure interface. The tank walls and supporting structure are defined with NASTRAN structural elements. The actual tank walls must be defined by two-dimensional membrane, panel or plate elements.

In addition to the special cards mentioned above, the following NASTRAN bulk data cards are used for special hydroelastic purposes:

1. GRID cards are used to define the fluid points. Fluid points contain only one degree of freedom and may not be connected to the structural elements.
2. GRAV cards are used to define the magnitude and direction of the gravity field. The set identification numbers are referenced by the fluid boundary data cards.
3. SPC and SPC1 data cards may be used to define constraints on the fluid grid points. These constraints are used to define regions of zero pressure in the fluid, such as a free surface without gravity effects or anti-symmetric boundary condition on a plane of symmetry. Only degree-of-freedom number 1 may be specified for a fluid grid point.

In addition, as indicated in Section 1.7.2.2, several optional parameters may be specified by the user for both direct and modal formulations. These parameters are in addition to those already provided in Rigid Format 3 and are entered in the Bulk Data Deck using the PARAM card. The parameters are described below. They are used to:

1. Control the optional computation paths,
2. Specify numerical factors to be used in the formulation, and
3. Allow blocks of DMAP statements to be turned "off" for restart from a previous checkpoint run.

<u>Direct Formulation Parameters</u>:

1. CØMPTYP (optional) default = -1

   Controls the type of compressibility calculations performed. A negative integer will cause finite compressibility as defined by the KCØMP parameter. A positive integer will cause constraint equation to be generated to provide pure incompressibility.
2. KCØMP (optional) default = 1.0

The real value of this parameter defines the overall compressibility of the fluid volume. The definition is fluid bulk modulus divided by total volume.

3. DIFSTIF (optional) default = 1

   A negative integer value causes the differential stiffness matrix to be included for ullage pressure effects. This matrix is available from the checkpoint file of a Rigid Format 4 solution run of the structure model.

4. DIFSCALE (optional) default = 1.0

   The differential stiffness matrix may be multiplied by the real value of this parameter.

5. NEWMØDE (optional) default = 1

   A negative integer will cause all DMAP statements and ALTERs up to the eigenvalue extraction to be skipped. This allows the user to restart the original solution to obtain different eigenvectors without changing the DMAP ALTER deck.

6. ØLDSTR (optional) default = 1

   A negative value will cause most structure-related processing to be skipped. This allows the user to restart a previous solution, either hydro or structure only, and change the fluid model without recomputing the unchanged structure.

Modal Formulation Parameters:

1. KCØMP (optional) default = 1.0

   (same as direct formulation parameter)

2. DIFSTIF (optional) default =1

   (same as direct formulation parameter)

3. DIFSCALE (optional) default = 1.0

   (same as direct formulation parameter)

4. NEWMØDE (optional) default = 1

   (same as direct formulation parameter)

5. ØLDSTR (optional) default = 1

   (same as direct formulation parameter)

6. LMØDES (optional) default = 1

   This integer value specifies the number of the lowest structure modes to be used when formulating the hydroelastic matrices. A negative value indicates all available modes are to be used.

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REFERENCE

1. Final Report, NASTRAN Hydroelastic Modal Studies, Volume I, Introduction, Theory and Results, (by Universial Analytics, Inc.), National Aeronautics and Space Administration, NASA-CR-150393, May 1977.

1.8 HEAT TRANSFER PROBLEMS

1.8.1 Introduction to NASTRAN Heat Transfer

NASTRAN heat flow capability may be used either as a separate analysis to determine temperatures and fluxes, or to determine temperature inputs for structural problems. Steady and transient problems can be solved, including heat conduction (with variable conductivity for static analysis), film heat transfer, and nonlinear (fourth power law) radiation.

The heat flow problem is similar, in many ways, to structural analysis (Figure 1). The same grid points, coordinate systems, elements, constraints, and sequencing can be used for both problems. There are several differences, such as the number of degrees of freedom per grid point, the methods of specifying loads, boundary film heat conduction, and the nonlinear elements. For heat flow problems, the only unknown at a grid point is the temperature (cf. structural analysis with three translations and three rotations), and hence, there is one degree of freedom per grid point. Additional grid or scalar points are introduced for fluid ambient temperatures in convective film heat transfer. If radiation effects are included or the conductivity of an element is temperature dependent, the problem becomes nonlinear (cf. structural analysis with temperature dependent materials which only requires looking up material properties and computing thermal loads).

The heat conduction analysis of NASTRAN is compatible with structural analysis. If the same finite elements are appropriate, then the same grid and connection cards can be used for both problems. As in structural analysis, the choice of a finite element model is left to the analyst. Temperature distributions can be output in a format which can be input into structural problems. Heat flow analysis uses many structural NASTRAN Bulk Data cards. These include (where i means there is more than one type): CBAR, CDAMPi, CELASi, CHEXAi, CIHEXi, CØNRØD, CØRDii, CQDMEM, CQUADi, CRØD, CTETRA, CTRAPRG, CTRIAi, CTRIARG, CTRMEM, CTUBE, CVISC, CWEDGE, DAREA, DELAY, DLØAD, DMI, DMIG, EPØINT, GRDSET, GRID, LØAD, MPC, MPCADD, NØLINi, ØMITi, PARAM, Piii (for elements requiring properties), PLØTEL, SEQiP, SLØAD, SPCi, SPCADD, SPØINT, TABLEDi, TABLEMi, TEMPii, TF, TLØADi, and TSTEP.

1.8.2 Heat Transfer Elements

The basic heat conduction elements are the same as NASTRAN structural elements. These elements are shown in the following table:

Heat Conduction Elements	
Type	**Elements**
Linear	BAR, RØD, CØNRØD, TUBE
Membrane	TRMEM, TRIA1, TRIA2, QDMEM, QUAD1, QUAD2
Solid of Revolution	TRIARG, TRAPRG
Solid	TETRA, WEDGE, HEXA1, HEXA2, IHEX1, IHEX2, IHEX3
Scalar	CELASi, CDMAPi

A connection card (Cxxx) and, if applicable, a property card (Pxxx) is defined for each of these elements. Linear elements have a constant cross-sectional area. The offset on the BAR is treated as a perfect conductor (no temperature drop). For the membrane elements, the heat conduction thickness is the membrane thickness. The bending characteristics of the elements do not enter into heat conduction problems. The solid of revolution element, TRAPRG, has been generalized to accept general quadrilateral rings (i.e., the top and bottom need not be perpendicular to the z-axis for heat conduction). These heat conduction elements are composed of constant gradient lines, triangles, and tetrahedra. The quadrilaterals are composed of overlapping triangles, and the wedges and hexahedra from subtetrahedra. Scalar spring elements are used for transient analysis temperature constraints and scalar damping elements are used to add thermal mass. Gradients and fluxes may be output by requesting ELFØRCE.

Thermal material conductivities and heat capacities are given on MAT4 (isotropic) and MAT5 (anisotropic) Bulk Data cards. Temperature dependent conductivities are given on MATT4 and MATT5 bulk data cards, which can only be used for nonlinear static analysis. The heat capacity per unit volume is specified, which is the product of density and heat capacity per unit mass (ρC_p). Lumped conductivities and thermal capacitance may be defined by the CELASi and CDAMPi elements, respectively.

A special element (HBDY) defines an area for boundary conditions. There are five basic types, called PØINT, LINE, REV, AREA3, and AREA4. A sixth type, ELCYL, is for use only with QVECT radiation. The HBDY is considered an element, since it can add terms to the conduction and heat capacity matrices. There is a CHBDY connection and PHBDY property card. When a film heat transfer condition is desired, film conductivity and heat capacity per unit area are specified on MAT4 data cards. The ambient temperature is specified with additional points (GRID or SPØINT) listed on the CHBDY connection card. See Figure 2 for geometry.

Radiation heat exchange may be included between HBDY elements. A list of HBDY elements must be specified on a RADLST Bulk Data card. The emissivities are specified on the PHBDY cards. The Stefan-Boltzmann constant (SIGMA) and absolute reference temperature (TABS) are specified on PARAM Bulk Data cards. Radiation exchange coefficients (default is zero) are specified on RADMTX Bulk Data cards.

The several types of power input to the HBDY elements can be output by the ELFØRCE request.

1.8.3 Constraints and Partitioning

Constraints are applied to provide boundary conditions, represent "perfect" conductors, and provide other desired characteristics for the heat transfer model.

Single point constraints are used to specify the temperature at a point. The grid or scalar points are listed on SPC or SPC1 bulk data cards, not GRDSET or GRID cards. The component on the data card must be "0" or "1". This declares the degree of freedom to be in the u_s set. The method of specifying temperature is dependent upon the problem type.

In linear statics analysis, the SPC or SPC1 card is used to constrain grid points at a fixed temperature. In nonlinear statics analysis, the SPC or SPC1 card is used to designate the grid point ID which is to be constrained. The actual value of the temperature is indicated on a TEMP card, selected by TEMP(MATERIAL) in the Case Control deck. In transient analysis, the SPC or SPC1 card may be used to fix the temperature of a grid point only when the temperature is zero. When the temperature is non-zero a large conductive coupling to a "ground" at absolute temperature must be defined. From the structural relationship F=Kx, the thermal analogy is made where K is the conductive coupling, F is an applied load, and x is the fixed temperature. In this case, x is adjusted to the desired temperature by defining the spring constant, K, of a CELASi element, which

is connected to "ground", and a load, F, which is applied to the grid point in question. The numerical value of K should be several orders of magnitude greater than the numerical value of the conductances prescribed for the rest of the model.

Multipoint constraints are linear relationships between temperatures at several grid points, and are specified on MPC cards. The first entry on an MPC card will be in the u_m set. The type of constraint is limited if nonlinear elements are present. If a member of set u_m touches a nonlinear (conduction or radiation) element, the constraint relationship is restricted to be an "equivalence". The term "equivalence" means that the value of the member of the u_m set will be equal to one of the members of the u_n set (a point not multipoint constrained). Those points not touching nonlinear elements are not so limited. The user will be responsible to satisfy the equivalence requirement, by having only two entries on the MPC data card, with equal (but opposite in sign) coefficients.

1.8.4 Thermal Loads

Thermal "loads" may be boundary heat fluxes or volume heat addition. As in the case of structural analysis, the method of specifying loads is different for static and transient analysis. The HBDY element is used for boundaries of conducting regions. Surface heat flux input can be specified for HBDY elements with QBDY1 and QBDY2 data cards. These two cards are for constant and (spatially) variable flux, respectively. Flux can be specified without reference to an HBDY elemen with the QHBDY data card. Vector flux, such as solar radiation, depends upon the angle between the flux and the element normal, and is specified for HBDY elements with the QVECT data card. This requires that the orientation of the HBDY element be defined. Volume heat addition into a conduction element is specified on a QVØL data card.

Static thermal loads are requested in Case Control with LØAD card. All of the above load types plus SLØAD's can be requested. Transient loads are requested in Case Control with a DLØAD card, which selects TLØAD time functions. Transient thermal loads may use DAREA (as in structural transient), and/or the QBDY1, QBDY2, QHBDY, QVECT, QVØL, and SLØAD cards. The resultant thermal load will be the sum of all loads applied. This means the LØAD SIDs and DAREA SIDs must be the same when referenced on a TLØADi card.

1.8.5 Linear Static Analysis

Linear static analysis uses APProach HEAT, SOLution 1. The rigid format is the same as that used for static structural analysis. This implies that several loading conditions and constraint

sets can be solved in one job, by using subcases in the Case Control deck.

1.8.6 Nonlinear Static Analysis

Nonlinear static analysis uses APProach HEAT, SØLution 3. This rigid format will allow temperature dependent conductivities of the elements, nonlinear radiation exchange, and a limited use of multipoint constraints. There is no looping for load and constraints. The solution is iterative. The user can supply values on PARAM Bulk Data cards for:

MAXIT (integer)	Maximum number of iterations (default 4).
EPSHT (real)	ε convergence parameter (default .001).
TABS (real)	Absolute reference temperature (default 0.0).
SIGMA (real)	Stefan-Boltzmann radiation constant (default 0.0).
IRES (integer)	Request residual vector output if positive (default -1).

The user must supply an estimate of the temperature distribution vector $\{u^1\}$. This estimate is used to calculate the reference conductivity plus radiation matrix needed for the iteration. $\{u^1\}$ is also used at all points in the u_s set to specify a boundary temperature. The values of $\{u^1\}$ are given on TEMP Bulk Data cards, and they are selected by TEMP(MATERIAL) in Case Control.

Iteration may stop for the following reasons:

1. Normal convergency: ε_T < EPSHT, where ε_T is the per unit error estimate of the temperatures calculated.
2. Number of iterations > MAXIT.
3. Unstable: $|\lambda_1| < 1$ and the number of iterations > 3, where λ_1 is a stability estimator.
4. Insufficient time to perform another iteration and output data.

The precise definitions are given in the NASTRAN Theoretical Manual, Section 8.4. Error estimates ε_p, λ_1, and ε_T for all iterations may be output with the Executive Control card DIAG 18, where ε_p is the ratio of the Euclidian norms of the residual (error) loads to the applied loads on the unconstrained degrees of freedom.

1.8.7 Transient Analysis

Transient analysis uses APProach HEAT, SØLution 9. This rigid format may include conduction, film heat transfer, nonlinear radiation, and NASTRAN nonlinear elements. Extra points are used as

in structural transient analysis. All points associated with nonlinear loads must be in the solution set. Loads may be applied with TLØAD and DAREA cards as in structural analysis. Also, the thermal static load cards can be modified by a function of time for use in transient analysis. If the static load data is used to define a transient load, the static load set identification is referenced on the TLØAD card in the DAREA field. Loads are requested in Case Control with DLØAD. Initial temperatures are specified on TEMP Bulk Data cards and are requested by IC. Previous static or transient solutions can be easily used as initial conditions, since they can be punched in the correct format. An estimate of the temperature $\{u^l\}$ is specified on TEMP Bulk Data cards for transient with radiation, and is requesed by TEMP(MATERIAL). The parameters available are:

TABS (real)	Absolute reference temperature (default 0.0).
SIGMA (real)	Stefan-Boltzmann radiation constant (default 0.0).
BETA (real)	Foreward difference integration factor (default .55).
RADLIN (integer)	Radiation is linearized if positive (default -1).

Time steps are specified on TSTEP data cards.

1.8.8 Compatibility with Structural Analysis

Grid point temperatures for thermal stress analysis (static structural analysis) are specified on TEMP Bulk Data cards. If punched output is requested in a heat conduction analysis for Rigid Formats 1 and 3, the format of the punched card is exactly that of a double field TEMP* data card. Thus, if the heat conduction model is the same as the structural model, the same grid, connection, and property cards can be used for both, and the temperature cards for the structural analysis are produced by the heat conduction analysis. The output request in Case Control is THERMAL(PUNCH).

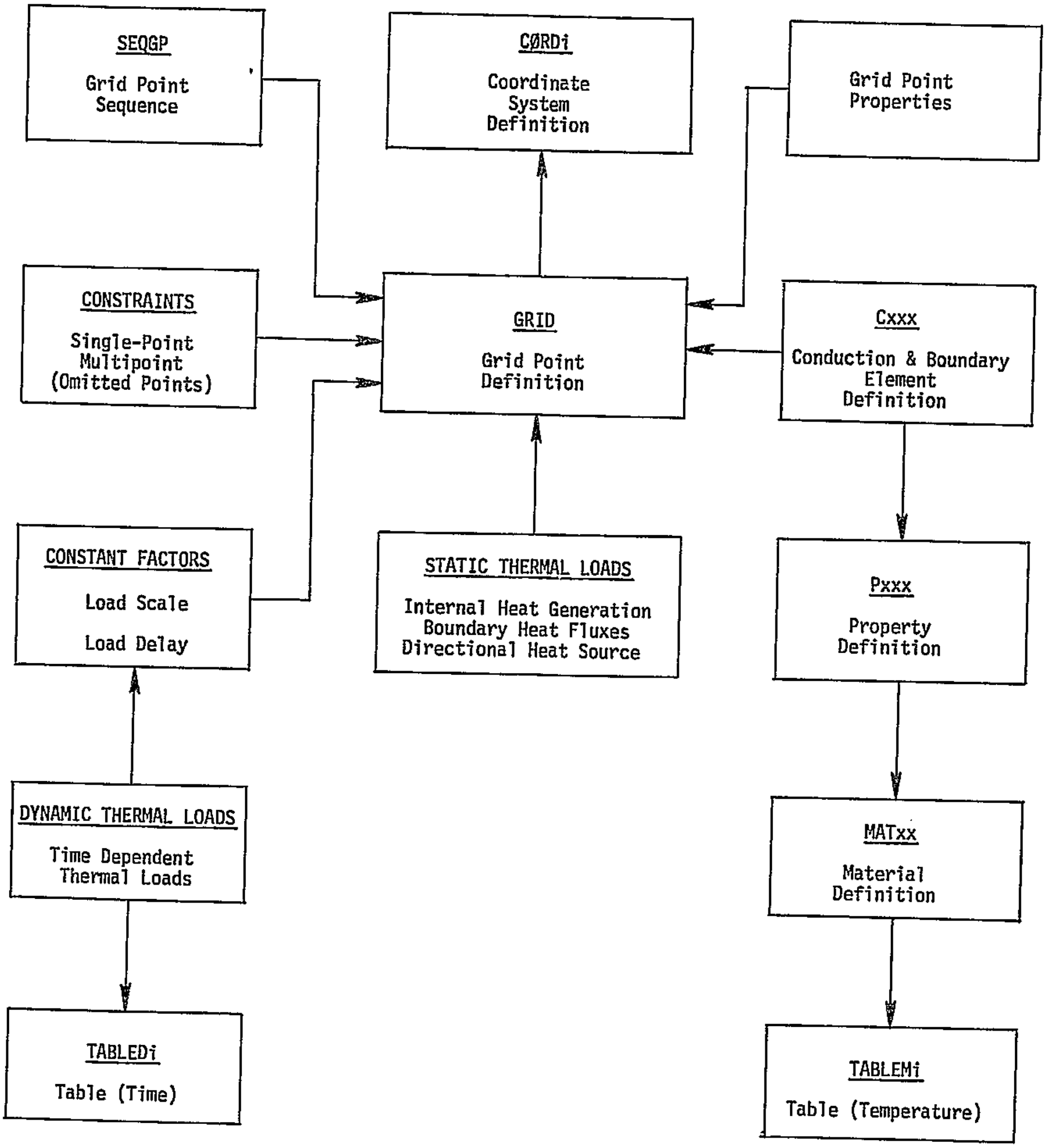
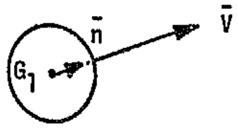


Figure 1. Thermal model diagram.

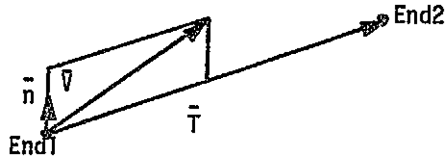
ORIGINAL PAGE IS OF POOR QUALITY

Type = PØINT



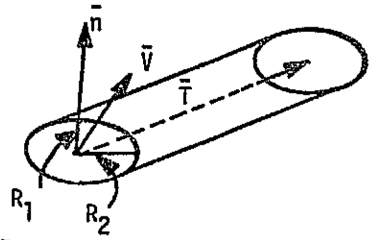
The unit normal vector is given by $\bar{n} = \bar{V}/|\bar{V}|$, where $\bar{V}$ is given in the basic system at the referenced grid point (see CHBDY data card, fields 16-18).

Type = LINE



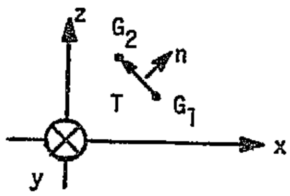
The unit normal lies in the plane of $\bar{V}$ and $\bar{T}$, is perpendicular to $\bar{T}$, and is given by $\bar{n} = (\bar{T} \times (\bar{V} x \bar{T}))/|\bar{T} \times (\bar{V} x \bar{T})|$.

Type = ELCYL



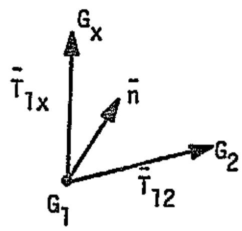
The same logic is used to determine $\bar{n}$ as for type = LINE. The "radius" R_1 is in the $\bar{n}$ direction, and R_2 is perpendicular to $\bar{n}$ and $\bar{T}$ (see fields 7 and 8 of PHBDY card).

Type = REV



The unit normal lies in the x-z plane, and is given by $\bar{n} = (\bar{e}_y \times \bar{T})/|\bar{e}_y \times \bar{T}|$. $\bar{e}_y$ is the unit vector in the y direction.

Type = AREA3 or AREA4



The unit normal vector is given by $\bar{n} = (\bar{T}_{12} \times \bar{T}_{1x})/|\bar{T}_{12} \times \bar{T}_{1x}|$, where x = 3 for triangles and x = 4 for quadrilaterals.

Figure 2. HBDY Element Orientation (for QVECT flux).

1.9 ACOUSTIC CAVITY MODELING

1.9.1 Data Card Functions

The NASTRAN structural analysis system is used as the basis for acoustic cavity analysis. Many of the structural analysis options such as selecting boundary conditions, applying loading conditions, and selecting output data are also available for acoustics.

The data cards specifically used for acoustic cavity analysis are described below. The card formats are exhibited in Section 2.4. Their purposes are analogous to the use of structural data cards. A gridwork of points is distributed over the longitudinal cross section of an acoustic cavity and finite elements are connected between these points to define the enclosed volume.

The points are defined by GRIDF data cards for the axisymmetric central fluid cavity and by GRIDS data cards for the radial slots. The GRIDF points are interconnected by finite elements via the CAXIF2, CAXIF3, and CAXIF4 data cards to define a cross sectional area of the body of rotation. The CAXIF2 element data card defines the area of the cross section between the axis and two points off the axis (the GRIDF points may not have a zero radius). The CAXIF3 and CAXIF4 data cards define triangular or quadrilateral cross sections and connect three or four GRIDF points respectively. The density and/or bulk modulus at each location of the enclosed fluid may also be defined on these cards.

The GRIDS points in the slot region are interconnected by finite elements via the CSLØT3 and CSLØT4 data cards. These define finite elements with triangular and quadrilateral cross-sectional shapes respectively. The width of the slot and the number of slots may be defined by default values on the AXSLØT data card. If the width of the slots is a variable, the value is specified on the GRIDS cards at each point. The number of slots, the density, and/or the bulk modulus of the fluid may also be defined individually, for each element on the CSLØT3 and CSLØT4 cards.

The AXSLØT data card is used to define the overall parameters for the system. Some of these parameters are called the "default" values and may be selectively changed at particular cross sections of the structure. The values given on the AXSLØT card will be used if a corresponding value on the GRIDS, CAXIFi, or CSLØTi is left blank. The parameters ρ (density) and B (bulk modulus) are properties of the fluid. If the value given for Bulk Modulus is zero the fluid is considered incompressible to the program. The parameters M (Number of slots) and W (slot width) are properties of the geometry. The parameter M defines the number of equally spaced slots

around the circumference with the first slot located at $\phi = 0°$. The parameter N (harmonic number) is selected by the user to analyze a particular set of acoustic modes. The pressure is assumed to have the following distribution

$$p(r,z,\phi) = p(r,z) \cos N\phi$$

If N = 0 the breathing and longitudinal modes will result. If N = 1 the pressure at $\phi = 180°$ will be the negative of the pressure at $\phi = 0°$. If N = 2, the pressures at $\phi = 90°$ and $\phi = 270°$ will be the negative of that at $\phi = 0°$. Values of N larger than M/2 have no significance.

The interface between the central cavity and the slots is defined with the SLBDY data cards. The data for each card consists of the density of the fluid at the interface, the number of radial slots around the circumference, and a list of GRIDS points that are listed in the sequence in which they occur as the boundary is traversed. In order to ensure continuity between GRIDF and GRIDS points at the interface, the GRIDF points on the boundary between the cylindrical cavity and the slots are identified on the corresponding GRIDS data cards rather than on GRIDF cards. Thus, the locations of the GRIDF points will be exactly the same as the locations of the corresponding GRIDS points.

Various standard NASTRAN data cards may be used for special purposes in acoustic analysis. The SPC1 data card may be used to constrain the pressures to zero at specified points such as at a free boundary. The formats for these cards are included in Section 2.4. Dynamic load cards, direct input matrices, and scalar elements may be introduced to account for special effects. The reader is referred to Sections 1.4 and 1.5 for instruction in the use of these cards.

1.9.2 Assumptions and Limitations

The accuracy of the acoustic model will be dependent on the selection of the mesh of finite elements. The assumption for each element is that the pressure field has a linear variation over the cross section and a sinusoidal variation around the axis in the circumferential direction. In areas where the pressure gradient changes are large, such as near a sharp corner, the points in the mesh should be placed closer together so that large changes in flow may be defined accurately by the finite elements.

The shape of the finite elements play an important part in the accuracy of the results. It has been observed that long narrow elements produce disproportionate errors. Cutting a large

square into two rectangles will not improve the results whereas dividing the square into four smaller squares may decrease the local error by as much as a factor of ten.

The slot portion of the cavity is limited to certain shapes because of basic assumptions in the algorithms. The cross section of the cavity normal to the axis must have a shape that is reasonably well defined by a central circular cavity having equally spaced, narrow slots. Various shapes are shown in Figure 1 in the order of increasing expected error.

It is recommended that shapes such as the cloverleaf and square cross section be analyzed with a full three dimensional technique. The assumption of negligible pressure gradient in the circumferential direction within a slot is not valid in these cases.

The harmonic orders of the solutions are also limited by the width of the slots. The harmonic number, N, should be no greater than the number of slots divided by two. The response of the higher harmonics is approximated by the slot width correction terms discussed in the NASTRAN Theoretical Manual, Section 17.1.

The output data for the acoustic analysis consists of the values of pressure in the displacement vector selected via the case control card "PRESSURE = i". The velocity vector components corresponding to each mode may be optionally requested by the case control card "STRESS = i", where i is the set number indicating the element numbers to be used for output, or by the words "STRESS = ALL". The "SET =" card lists the element or point numbers to be output.

Plots of the finite element model and/or of the pressure field may be requested with the NASTRAN plot request data cards. The central cavity cross section will be positioned in the XY plane of the Basic Coordinate System of NASTRAN. The slot elements are offset from the XY plane by the width of the slot in the +Z direction. The radial direction corresponds to X and the axial direction corresponds to the Y direction. Pressures will be plotted in the Z direction for both the slot points and the central cavity points. The case control data cards for plotting are documented in the User's Manual. The PLØTEL elements are used for plotting the acoustic cavity shape. The plot request card "SET n INCLUDE PLØTEL" must be used where n is a set number.

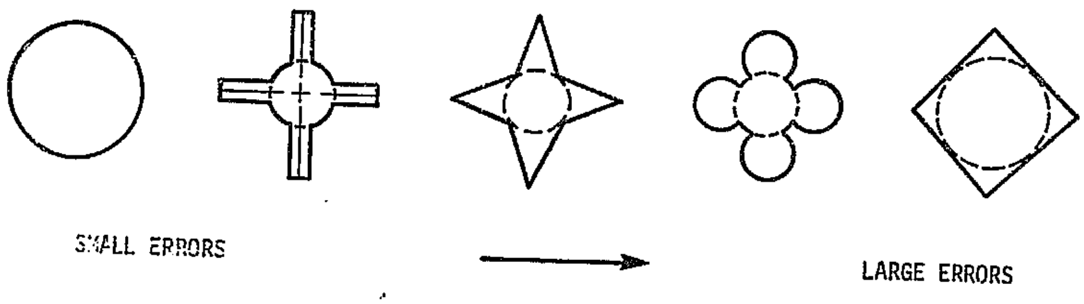


Figure 1. Modeling errors for various shapes.

1.10 SUBSTRUCTURING

Substructuring is an analytical technique used to facilitate the solution of structural problems by subdividing the structural models into smaller, more manageable components. The most elementary component, or basic substructure, is modeled separately just as any finite element model would be. These basic substructures are combined to build more complex substructures which, in turn, can be progressively combined with other substructures in stages to eventually arrive at the final desired solution model. Once the solution model is analyzed, the results at each stage of the combination process may be recovered until, ultimately, the detailed solution data are recovered for each of the original basic substructures. In effect, substructuring is an extension of basic finite element theory itself whereby the usual simple beam, plate, and solid elements are replaced by basic substructures which themselves may be viewed as components of even more complex substructures.

Substructure analysis is logically performed in at least three phases as follows:

Phase 1 - Analysis of each individual substructure by NASTRAN to produce a description, in matrix terms, of its properties as seen at the boundary degrees of freedom, u_a.

Phase 2 - Combination of the matrix properties from Phase 1 and the inclusion, if desired, of additional terms to form a "pseudostructure," which is then analyzed by NASTRAN.

Phase 3 - Completion of the analysis of individual substructures using the $\{u_a\}$ vector produced in Phase 2.

To provide maximum program flexibility, both the manual and automated approaches to substructuring are available. The manual approach requires user-generated DMAP alters and can be used in all Rigid Formats except for Piecewise Linear Analysis. The procedures for single-stage, manual substructuring are discussed and illustrated with a complete and fully annotated example of the input in Section 1.10.1. In Section 1.10.2, the automated multi-stage substructuring capabilities available for Rigid Formats 1, 2, 3, 8 and 9 are presented.

Unlike the manual substructuring procedures, the automated capabilities provide for:

1. Simple commands to control execution and data recovery at all stages of analysis.
2. Automatically generated DMAP alters.
3. Automated procedures to control and maintain the extensive data files required.
4. Data storage on single direct access file (minimizes or eliminates checkpoint/restart tapes).
5. Data transfer among IBM, CDC, or UNIVAC computers at any stage in the analysis.

6. No restrictions on grid point and element numbering.

7. Modeling only one of two or more identical substructure components.

It should be noted that cyclic symmetry is available as an alternate formulation for substructuring structures with rotational or dihedral symmetry. This capability is described in Section 1.12. The more general approaches are described below starting with the manual, single-stage substructuring, followed by the automated multi-stage substructuring capabilities.

1.10.1 Manual Single-Stage Substructuring

The theoretical basis for NASTRAN manual substructuring is given in Section 4.3 of the Theoretical Manual. This technique may be used with any of the rigid formats, except Piecewise Linear Analysis. The following sections present instructions, including Series Ø DMAP alters for use with two of the rigid formats, Static Analysis and Normal Modes Analysis.

Manual substructure analysis, as here defined, is a procedure in which the structural model is divided into separate parts which are then processed in separate computer executions to the point where the data blocks required to join each part to the whole are generated. The subsequent operations of merging the data for the substructures and of obtaining solutions for the combined problem are performed in one or more subsequent executions, after which detailed information for each substructure is obtained by additional separate executions.

The NASTRAN Data Deck for each of the substructures is constructed in the same manner as a NASTRAN analysis without substructuring. The following restrictions must be considered when forming the NASTRAN Data Deck for each of the substructures:

1. All points on boundaries between substructures which are to be joined must have their free (unconstrained) degrees of freedom placed in the a-set.

2. The sequence of internal grid point identification numbers along the boundary between any two substructures must be in the same order. The internal sequence is the external sequence modified by any SEQGP cards. For example, if one substructure had boundary grid point internal identification numbers of 3, 4, 9, 27, and 31, the adjoining substructure could have a corresponding set of internal grid point identification numbers of 7, 11, 21, 22, and 41, but not 7, 11, 22, 21, and 41. This restriction is automatically satisfied if the same grid point numbers, without SEQGP cards, are used on the boundaries for connected substructures.

3. The displacement coordinate system for each group of connected grid points on the boundaries between substructures must be the same.

4. Elements located on the boundary may be placed in either adjacent substructure.

5. The loads applied to boundary points may be arbitrarily distributed between the adjoining substructures. Care should be exercised not to duplicate the loads by placing the entire load on each substructure.

6. The constrained stiffness matrix, $[K_{oo}]$, for each substructure must be nonsingular. This requirement is automatically satisfied in most cases, since usually there are enough degrees of freedom on the boundary of the substructure to account for its rigid body motions. In exceptional cases, such as when the substructure is a hinged appendage, it may be necessary for the user to assign additional degrees of freedom to u_a, rather than u_o via ASET cards.

Although the following discussion is limited to single-stage substructuring, there is no inherent restriction on the use of multi-stage substructures in NASTRAN. In multi-stage substructuring, some of the substructures are precombined in Phase 2 to form intermediate substructures. The final combination in Phase 2 then consists of joining two or more intermediate substructures. This procedure will be useful if there are several substructures in the model, and changes are made in only one or a few substructures. In this case, the amount of effort and computer time required for changes in the model can be substantially reduced if the unchanged substructures are initially combined into a single intermediate substructure.

1.10.1.1 Basic Manual Substructure Analysis

Basic manual substructure analysis will be described with reference to the simple beam structure shown in Figure 1. The beam is arbitrarily separated into two substructures, referred to as substructure 1 and substructure 2, with a single boundary point being located at grid point 3. The beam is supported at grid points 1 and 6. No loads are applied to substructure 1. A single load is applied to substructure 2 at grid point 4, and a single load is applied at the boundary to grid point 3.

The complete NASTRAN Data Decks for all three phases of a substructure analysis for the beam shown in Figure 1 are presented in Tables 1, 3, 5, 7, and 9. The integers in the left-hand column are used to relate the respective discussions in Tables 2, 4, 6, 8, and 10 to the cards in the NASTRAN Data Decks.

It should be noted that no output has been requested in the Case Control Deck for substructure 1. If the user wishes to have a plot of the undeformed structure for checking the model, a Plot Package can be inserted in the Case Control Deck in the usual way, as described in Section 4.2.

The partitioning matrix gives the relationship between the internal indices associated with the a-set matrices generated in Phase 1 and the external grid point component definition given on the GRID cards that are input to Phase 1 as modified by any SEQGP cards. The same internal indices in Phase 1 for the a-set are redefined in Phase 2 as the indices for the g-set. The word "pseudostructure" is associated with the g-size matrices used in Phase 2.

The partitioning matrix for the problem under consideration is given as follows:

PARTITIONING MATRIX

Internal Index	External Grid-Component	
	Substructure 1	Substructure 2
1	3-1	3-1
2	3-2	3-2
3	3-6	3-6

The procedure for constructing a partitioning matrix is as follows:

1. Select any one of the substructures and list the components of the a-set in sequence by grid point and component number as modified by any SEQGP cards(internal sequence). These are the nonzero entries in the partitioning vector for the first substructure.
2. Build the second column of the partitioning matrix by selecting any connected substructure and entering the connected components in the same row as the associated components in the first substructure.
3. Enter all unconnected a-set components in unoccupied rows of the partitioning matrix according to their internal sequence numbers. Unconnected members of the a-set having internal sequence numbers in the range of the connected components will create new intermediate rows in the previously formed columns of the matrix.
4. Build the remaining columns of the partitioning matrix, one for each substructure, by following a similar procedure for all remaining substructures. In each case, first enter all components that are connected to the previously selected substructure or

substructures, followed by the remaining unconnected components in their internal sequence.

5. The rows of the partitioning matrix are associated with the sequence of the internal indices for the scalar points in the pseudostructure. Any sequential set of integers may be used to identify these scalar points in Phase 2.

6. The columns of the partitioning matrix (one vector for each substructure) are input with Direct Matrix Input (DMI) cards. The input matrix contains real 1's in all locations in the partitioning matrix having grid point-component entries. See Section 2.4 for DMI card format.

The DMI cards (121 and 122 in Table 1) in the sample problem give the name E1 to the partitioning vector for substructure 1. The first card defines the partitioning vector as being rectangular and consisting of real single-precision entries. The next to the last entry on the first card indicates there are three rows in the g-set matrices input to Phase 2. The second integer 1 on the second card indicates that the first internal index is associated with one of the components in substructure 1; in this case, grid point 3, component 1. The three real 1.0's indicate the first three internal indices are associated with components in substructure 1; in this case, grid point 3, components 1, 2, and 6. In this particular case, only the initial two steps are required to construct the partitioning matrix and the partitioning vector for substructure 2 will be identical to that for substructure 1. This results from the fact that the single boundary point in this problem is a part of both substructures.

The partitioning vectors are not needed until Phase 2. They were arbitrarily input to Phase 1 so they could be included on the User Tape, along with the output matrices from Phase 1.

The NASTRAN Data Deck for substructure 2 is given in Table 3. For identification purposes, the cards are arbitrarily numbered beginning with 150.

The Phase 2 operations are concerned with merging the a-set matrices generated in Phase 1 which define the g-size pseudostructure in Phase 2. The NASTRAN Data Deck for Phase 2 is given in Table 5. The cards are arbitrarily numbered beginning with 201.

Although the data deck shown in Table 5 is prepared for two substructures, it was constructed in such a manner that it could be easily extended to more than two substructures. If there are more than two substructures, cards similar to 216 to 222, 232, and 233 need to be added to the NASTRAN data deck for each additional substructure.

The final part of a substructure analysis is to perform data recovery for each substructure of interest. These runs are made as a restart of the Phase 1 runs. Any of the normal rigid format output can be requested, including both undeformed and deformed structure plots. All of the output will be in terms of the elements and grid points defined in the Phase 1 Bulk Data Decks. The NASTRAN Data Deck for the Phase 3 analysis of substructure 1 is given in Table 7.

The NASTRAN data deck for the Phase 3 analysis of substructure 2 is given in Table 9. Comments are restricted to cards that are different from those presented for the Phase 3 run of substructure 1.

1.10.1.2 Loads and Boundary Conditions

The single load and the single boundary condition for the sample problem defined in Section 1.10.1.1 were introduced in Phase 1. It is also possible to introduce loads and boundary conditions in Phase 2. In this case, the loaded and/or constrained degrees of freedom must be included in the a-set for Phase 1, so they will be a part of the pseudostructure in Phase 2. Loads are applied to the pseudostructure in Phase 2 with the SLØAD card. This limits the type of load that can be applied in Phase 2 to directly applied loads. Other loading conditions depending on element properties or connection data, such as thermal loads, gravity loads, and pressure loads, must be applied in Phase 1. Loads may be introduced in both Phases 1 and 2, as the suggested DMAP sequence will add contributions to the load vector from both phases. The lack of generality for the application of loads in Phase 2 will often dictate that static loads be applied in Phase 1.

The loads and boundary conditions for the sample problem can be applied in Phase 2 if the modifications shown in Tables 11 and 12 are made to the NASTRAN Data Decks presented in Section 1.10.1.1.

The modified partitioning matrix with grid points 1, 3, 4, and 6 in the a-set is shown below.

PARTITIONING MATRIX

Internal Index	External Grid-Component Substructure 1	External Grid-Component Substructure 2
1	1-1	
2	1-2	
3	1-6	
4	3-1	3-1
5	3-2	3-2
6	3-6	3-6
7		4-1
8		4-2
9		4-6
10		6-1
11		6-2
12		6-6

The modified partitioning matrix contains twelve scalar points, with six in substructure 1, nine in substructure 2, and three common to both substructures. The loads are now located at scalar points 5 and 8, as indicated on card 246a. The single-point constraints are located at scalar points 1, 2, and 11, as indicated on card 246b. The modified partitioning vector for substructure 1 indicates there are twelve degrees of freedom in the pseudostructure, and that, beginning with the first scalar point, there are six scalar points associated with substructure 1. The modified partitioning vector for substructure 2 indicates the first entry is associated with scalar point 4, and that there are a total of nine scalar points associated with substructure 2.

If multiple loading conditions are used in the solution, the subcase structure must be established in Phase 1. In order to perform the matrix operations in Phase 2, the same case control structure must be used for all substructures. This means that the same number of subcases must be defined for each substructure, even though some of the subcases will not contain a load selection or any other entries. NASTRAN will generate a null column in the load matrix for all subcases for which no load set is selected. If any loads are applied in Phase 2, the

same subcase structure must be used in Phase 2. In any event, the subcase structure established in Phase 1 must be used in Phase 3. The contents of each subcase in Phase 3 will relate to output selections, rather than load and boundary condition selections.

Consider adding two additional loading conditions to the sample problem in Section 1.10.1.1. If one additional loading condition were applied to substructure 1, identified as 202, and one additional loading to substructure 2, identified as 203, the subcase structure established in Phase 1 would appear as follows:

Substructure 1	Substructure 2
SPC = 101	SPC = 201
SUBCASE 1	SUBCASE 1
	LØAD = 201
SUBCASE 2	SUBCASE 2
LØAD = 202	
SUBCASE 3	SUBCASE 3
	LØAD = 203

Load case 202 would have to be defined with some form of static loading in the Bulk Data Deck for Phase 1 of substructure 1. In addition, load set 203 would have to be defined with some form of static loading in the Bulk Data Deck for Phase 1 of substructure 2.

The DMAP sequence for the sample problem in Section 1.10.1.1 will not support multiple boundary conditions in Phase 1. If multiple boundary conditions are introduced in Phase 1, it is necessary to generate a separate partitioning vector for use in Phase 2 for each of the unique boundary conditions. In some sense, this results in the definition of a number of separate problems equal to the number of unique boundary conditions. Although a DMAP sequence could be developed to support multiple boundary conditions in Phase 1, it is not recommended that multiple boundary conditions be introduced into Phase 1.

Multiple boundary conditions may be introduced in Phase 2 without any difficulty. However, in order to handle the internal looping for each boundary condition, it is more convenient if the loads are also introduced in Phase 2. As indicated earlier, the introduction of loads in Phase 2 does limit the manner in which the static loads can be defined. If the

loads and boundary conditions are introduced in Phase 2, all of the case control options for combining subcases, including symmetry combinations, may be used in the usual manner.

It is possible to introduce the loads in Phase 1 and multiple boundary conditions in Phase 2. However, provision must be made to generate all loading conditions in Phase 1, which will automatically take place if one subcase is defined for each loading condition and no boundary conditions are mentioned in the Phase 1 Case Control Deck. It is then necessary in Phase 2 to partition out the proper columns of the loading matrix for each loop or boundary condition in Phase 2. This requires that the user construct the proper partitioning vector for each boundary condition. Also, appropriate modifications would have to be made to the suggested DMAP sequence for Phase 2.

1.10.1.3 Normal Modes Analysis

Substructuring for normal modes analysis is performed in much the same way as that for static analysis. A NASTRAN Data Deck for use in Phase 1 of a Normal Modes Analysis (Rigid Format 3) is shown in Table 13.

Note that the ØUTPUT1 module writes the mass matrix, as well as the stiffness matrix and partitioning vector on User Tape 1. The Case Control Deck is similar to the Phase 1 deck for static analysis. It must include a constraint selection if the boundary conditions are applied in Phase 1. The Bulk Data Deck is also similar to that used in Phase 1 for static analysis. In general, it includes all the cards associated with the definition of the model and the DMI cards for the definition of the partitioning vector. It will also include cards for the definition of the a-set and other constraint cards if the boundary conditions are applied in Phase 1. As in static analysis, one such deck must be prepared for each substructure.

The NASTRAN Data Deck for Phase 2 of Normal Modes Analysis with two substructures is shown in Table 14.

The Phase 2 NASTRAN Data Deck for Normal Modes Analysis is similar to that used for Static Analysis. The following comments are related to differences in the two decks:

1. Since there are no loads associated with a normal modes analysis, the module GP3 is not executed.
2. The same operations are performed on the mass matrix as are performed for the stiffness matrix.

3. The data block LAMA (Eigenvalue Summary) is written as the first data block on User Tape 3. This is followed by the appropriate partitions of the eigenvectors for each of the substructures.

4. The Case Control Deck must include a method selection for eigenvalue extraction.

5. The Bulk Data Deck is similar to that used in static analysis, except that a null matrix must be defined for the mass matrix, instead of the load matrix (since matrix assembly is not required), and an EIGR card must be included.

The Phase 3 data deck for Normal Modes Analysis, given in Table 15, is similar to that used for Static Analysis. The first reference to module INPUTT1 is to read the data block LAMA, which is the first data block on User Tape 3. The second reference to INPUTT1 is to read the proper partition of the eigenvectors. The zero parameter at the end of the statement should be incremented one for each substructure in order to point to the proper eigenvector partition.

1.10.1.4 Dynamic Analysis

Manual substructuring may be used with any of the other dynamics rigid formats. The NASTRAN Data Decks will be similar to those used for Normal Modes Analysis. All dynamic loads must be applied in Phase 2. If the SUPØRT card is needed to define free body motions for the structure as a whole, it must be included in Phase 2.

In dynamic analysis, the a-set will include, in addition to all points on the boundary of the substructure, a number of points within each substructure sufficient to define the dynamic response. Since all active degrees of freedom along interior boundaries must be included in u_a, the a-set will contain more degrees of freedom than are needed in dynamic analysis, with a large resulting inefficiency for a very small gain in accuracy. This is a serious consideration because, due to the high density of K_{aa}, the time to perform most of the significant matrix operations in Phase 2 increases nearly as the cube of the number of degrees of freedom in u_a. The situation can be greatly improved by a second stiffness reduction in Phase 2, in which u_a is partitioned into a set, u_c, that will be retained in dynamic analysis, and a set, u_b, that will be eliminated. The u_b set includes the excess degrees of freedom on the interior boundaries. The second stiffness reduction in Phase 2 is defined by listing the members of the u_b set that will be eliminated on ØMIT cards. These omitted degrees of freedom must reference the scalar points associated with the pseudostructure.

In Phase 3 for dynamics, each NASTRAN substructure is restarted with the partition of the Phase 2 solution vector, or eigenvector, for each substructure. All normal data reduction

procedures may then be applied. In dynamic analysis, Phase 3 can be omitted if output requests are restricted to the response quantities for the scalar points of the pseudostructure. In this case, the output and partition modules can be omitted from the Phase 2 runs, as their only purpose is to serve as input for the Phase 3 runs. If output is desired for dependent response quantities or element stresses and forces, a Phase 3 run must be made for each substructure of interest.

1.10.1.5 DMAP Loops for Phase 2

The DMAP sequences for the substructure example in Section 1.10.1.1 uses repeated blocks of code for each substructure. Cards 209 through 215 are associated with input for substructure 1. Cards 216 through 222 perform the same operations for substructure 2. Likewise, cards 230 and 231 are associated with output for substructure 1, and cards 232 and 233 are associated with output for substructure 2. If a large number of substructures are used, it is more convenient to use a DMAP loop, rather than repeating blocks of code. DMAP loops are constructed by placing a LABEL statement at the beginning of the loop and an REPT statement at the end of the loop. The number of times the REPT statement must be executed is set by an integer constant.

The series of statements represented by cards 209 through 222 (in Table 5) can be replaced with the following sequence of DMAP operations:

```
PARAM     // C,N,NØP / V,N,INP=1 $
LABEL     BLØCK1 $
INPUTT1   / E,KGGA,PGA,, / C,N,-3 / V,N,INP $
MERGE,    ,,,KGGA,E, / KGGTA $
ADD       KGG,KGGTA / KTA $
EQUIV     KTA,KGG / TRUE $
MERGE,    ,PGA,,,,E / PGTA / C,N,1 $
ADD       PGT,PGTA / PTA $
EQUIV     PTA,PGT / TRUE $
PARAM     // C,N,ADD / V,N,INP / V,N,INP / C,N,1 $
REPT      BLØCK1,1 $
```

The LABEL, BLØCK1, is shown at the beginning of the loop, and the REPT statement is shown at the end. The integer in the REPT statement is set to one less than the number of substructures,

which in this case is one. The PARAM statement preceding the REPT statement is used to increment the second parameter of INPUTT1 by one each time through the loop. This causes the information to be read from a different tape each time through the loop. This DMAP loop does not check the label before reading the information on the input tape. The fact that the same names are used for the matrices each time through the loop does not cause any difficulty, as the matrices are located by their position on the tape, rather than by name.

If a DMAP loop is used for the input sequence, consideration must be given to its effect on the output sequence. Since the partitioning vectors were not saved on each pass through the DMAP loop for the input sequence, it is necessary to recover this information for use in the output sequence. This might be done by rerunning INPUTT1 to reread the partitioning vectors as needed, or perhaps by inserting the DMI cards for the partitioning vectors in the Bulk Data Deck for Phase 2. If Phase 3 runs are not required, no output sequence is necessary.

1.10.1.6 Identical Substructures

In the case of identical substructures, the substructuring procedures can be organized to take full advantage of the repetitive parts. The substructures only have to appear identical in Phase 1. The loading conditions and boundary conditions used in Phase 2 may be quite different for the otherwise identical substructures. The Phase 1 substructures must have identical geometry, including the global coordinate systems used on the boundary grid points.

Only a single Phase 1 run is made for each group of identical substructures. Since the identical substructures will be coupled in different ways during Phase 2, a different partitioning vector must be generated for each use of the identical substructures in Phase 2. These multiple partitioning vectors can be placed on the same output tape from Phase 1, which also contains the single set of structural and loading matrices for the group of identical substructures.

The user may choose to make one or more Phase 3 runs for the members of a group of identical substructures. If the loading conditions and boundary conditions are also identical for the group of identical substructures, a single Phase 3 run will give all information of interest. However, if the boundary conditions and/or loading conditions are different for the various members of the group of identical substructures, it will probably be desirable to make a separate Phase 3 run for each of the substructures used in the complete structural model.

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The use of identical substructures not only saves time in computer runs for Phase 1 and perhaps for Phase 3, but also substantially reduces the effort associated with the preparation of the structural model in the Bulk Data Deck. In some sense, substructuring procedures with identical substructures can be thought of as being a form of data generation. Although substructuring is usually used because of problem size, it may be desirable, in some cases, to use substructuring because of the repetitive nature of the structure, and a consequent saving in data generation effort.

Table 1. Data Deck for Phase 1 of Substructure 1.

```
NASTRAN   FILES = (INPT,NPTP)
ID        PHASE,ØNE $ SUBSTRUCTURE 1
TIME      2
CHKPNT    YES
APP       DISP
SØL       1,9
ALTER     n1 $ (where n1 = DMAP statement number of EQUIV KAA,KLL/REACT
JUMP      LBL7 $
ALTER     n2 $ (where n2 = DMAP statement number of LABEL LBL10)
FBS       LØØ,UØØ,PØ/UØØV $
CHKPNT    UØØV $
ØUTPUT1   E1,KLL,PL,,//C,N,-1/C,N,0/C,N,USERTP1 $
ALTER     n3,n4 $ (where n3 = DMAP statement number of SSG3 module and
ENDALTER                 n4 = DMAP statement number of REPT LØØPTØP,360)
CEND
TITLE = PHASE ØNE - SUBSTRUCTURE 1
SPC = 101
BEGIN BULK
```

1	2	3	4	5	6	7	8	9	10
ASET	3	126							
CBAR	1	10	1	2		1.0		1	
CBAR	2	10	2	3		1.0		1	
DMI	E1	0	2	1	1		3	1	
DMI	E1	1	1	1.0	1.0	1.0			
GRID	1						345		
GRID	2		240.				345		
GRID	3		480.				345		
MAT1	11	30.+6							
PBAR	10	11	60.	500.					
SPC	101	1	12						
ENDDATA									

Table 2. Comments for Phase 1, Substructure 1 Data Deck.

Card No.	Refer to Table 1 for input cards described below.
103	This run will be checkpointed, so that a restart can be made for Phase 3. The user must allocate space for the checkpoint file, NPTP. (The NPTP file is presumed to be copied to tape at the end of the job.)
105	Rigid Format 1, Static Analysis, will be used for this problem without property optimization.
106	Insert the following statement after DMAP statement EQUIV KAA,KLL/REACT.
107	Jump around the Rigid Body Matrix Generator modules. The solution for $\{u_a\}$ will be performed in Phase 2.
108	Insert the following three statements after DMAP statement LABEL LBL10.
109	Use the module FBS to solve for $\{u_o^o\}$ the displacement of the o-set relative to the a-set points.
110	Write displacement vector UØØV on the New Problem Tape.
111	Use the module ØUTPUT1 to write the DMI matrix given on cards 121 and 122, along with the stiffness matrix KLL, and the load vector PL on User Tape 1 (USERTP1). The user must allocate space for the User Tape file, INPT. (The INPT file is presumed to be copied to tape at the end of the job.) The details of the call for DMAP module ØUTPUT1 and other DMAP information are given in Section 5.
112	Delete the data recovery modules (SSG3 thru REPT LØØPTØP,360).
116	Select single-point constraint set 101.
118	Defines grid point 3 as a boundary point between substructures.
119, 120	Connection cards defining bar elements in substructure 1.
121, 122	Direct Matrix Input cards that define the partitioning vector for use in Phase 2. The entries on these cards are discussed below.
123, 124, 125	These cards define the grid points in substructure 1.

(Continued)

Table 2. Comments for Phase 1, Substructure 1 Data Deck (continued).

Card No.	Refer to Table 1 for input cards described below.
126	Defines the material for the elements in substructure 1.
127	Defines the properties of the elements in substructure 1.
128	Defines single-point constraint set 101. Components 1 and 2 are constrained at grid point 1 in substructure 1.

Table 3. Data Deck for Phase 1, Substructure 2.

```
150a NASTRAN   FILES = (INPT,NPTP)
150b ID        PHASE,ØNE $ SUBSTRUCTURE 2
151  TIME      2
152  CHKPNT    YES
153  APP       DIAP
154  SØL       1,9
155  ALTER     n1 $ (where n1 = DMAP statement number of EQUIV KAA,KLL/REACT)
156  JUMP      LBL7 $
157  ALTER     n2 $ (where n2 = DMAP statement number of LABEL LBL10)
158  FBS       LØØ,UØØ,PØ/UØØV $
159  CHKPNT    UØØV $
160  ØUTPUT1   E2,KLL,PL,,//C,N,-1/C,N,0/C,N,USERTP2 $
161  ALTER     n3,n4 $ (where n3 = DMAP statement number of SSG3 module and
                          n4 = DMAP statement number of REPT LØØPTØP,360)
162  ENDALTER
163  CEND
164  TITLE = PHASE ØNE - SUBSTRUCTURE 2
165  SPC = 201
166  LØAD = 202
167  BEGIN BULK
```

	1	2	3	4	5	6	7	8	9	10
168	ASET	3	126							
169	CBAR	3	10	3	4		1.0		1	
170	CBAR	4	10	4	5		1.0		1	
171	CBAR	5	10	5	6		1.0		1	
172	DMI	E2	0	2	1	1		3	1	
173	DMI	E2	1	1	1.0	1.0	1.0			
174	FØRCE	202	3		1000.		-1.0			
175	FØRCE	202	4		1000.		-1.0			
176	GRID	3		480.				345		
177	GRID	4		720.				345		

(Continued)

Table 3. Data Deck for Phase 1, Substructure 2 (continued).

	1	2	3	4	5	6	7	8	9	10
178	GRID	5		960.				345		
179	GRID	6		1200.				345		
180	MAT1	11	30.+6							
181	PBAR	10	11	60.	500.					
182	SPC	201	6	2						
183	ENDDATA									

Table 4. Comments for Phase 1, Substructure 2 Data Deck.

Card No.	Refer to Table 3 for input cards described below.
160	The partitioning vector for substructure 2 is written on User Tape 2 and is named E2. The user must allocate space for User Tape file, INPT. (The INPT file is presumed to be copied to tape at the end of the job.) It is possible to change the ØUTPUT1 statement and write the results for substructure 2 on the same tape as for substructure 1, if desired.
165	Selects single-point constraint set 201.
166	Selects load set 202.
172, 173	Other than the name E2, the partitioning vector is identical to that for substructure 1.
174, 175	Defines the external loads in load set 202. The load applied to grid point 3 has arbitrarily been placed in substructure 2.
182	Defines single-point constraint set 201 at grid point 6, component 2.

Table 5. Data Deck for Phase 2

```
200  NASTRAN   FILES = (INPT,INP1,INP2)
201  ID        PHASE,TWØ
202  TIME      2
203  APP       DISP
204  SØL       1,9
205  ALTER     n0 $ (where n0 = DMAP statement number of the BEGIN statement)
206  PARAM     //C,N,NØP/V,N,TRUE=-1 $
207  ALTER     n1,n2 $ (where n1 = DMAP statement number of module GP2 and
                              n2 = DMAP statement number of LABEL P1)
208  ALTER     n3,n4 $ (where n3 = DMAP statement number of PARAM just before TA1 and
                              n4 = DMAP statement number of LABEL LBL11A)
209  INPUTT1   /E01,KGG01,PG01,,/C,N,-1/C,N,1/C,N,USERTP1 $
210  MERGE,    ,,,KGG01,E01,/KGGT01 $
211  ADD       KGG,KGGT01/KT01 $
212  EQUIV     KT01,KGG/TRUE $
213  MERGE,    ,PG01,,,,E01/PGT01/C,N,1 $
214  ADD       PGT,PGT01/PT01 $
215  EQUIV     PT01,PGT/TRUE $
216  INPUTT1   /E02,KGG02,PG02,,/C,N,-1/C,N,2/C,N,USERTP2 $
217  MERGE,    ,,,KGG02,E02,/KGGT02 $
218  ADD       KGG,KGGT02/KT02 $
219  EQUIV     KT02,KGG/TRUE $
220  MERGE,    ,PG02,,,,E02/PGT02/C,N,1 $
221  ADD       PGT,PGT02/PT02 $
222  EQUIV     PT02,PGT/TRUE $
223  ALTER     n5,n6 $ (where n5 = DMAP statement number of CØND LBL4,GENEL and
                              n6 = DMAP statement number of LABEL LBL4)
224  ALTER     n7,n7 $ (where n7 = DMAP statement number of module SSG1)
225  SSG1      SLT,BGPDT,CSTM,SIL,,MPT,,EDT,,CASECC,DIT/PG/V,N,LUSET/V,N,NSKIP $
226  ADD       PGT,PG/PGX $
227  EQUIV     PGX,PG/TRUE $
228  ALTER     n8,n9 $ (where n8 = DMAP statement number of the first SDR2 module and
                              n9 = DMAP statement number of ØFP just before XYTRAN)
229  ØUTPUT1,  ,,,,//C,N,-1/C,N,0/C,N,USERTP3 $
```

(Continued)

Table 5. Data Deck for Phase 2 (continued).

```
230  PARTN      UGV,,E01/,ULV01,,/C,N,1 $
231  ØUTPUT1    ULV01,,,,//C,N,0/C,N,0/C,N,USERTP3 $
232  PARTN      UGV,,E02/,ULV02,,/C,N,1 $
233  ØUTPUT1    ULV02,,,,//C,N,0/C,N,0/C,N,USERTP3 $
234  SDR2       CASECC,CSTM,MPT,DIT,EQEXIN,SIL,,,BGPDT,PGG,QG,UGV,,/
                ØPG1,ØQG1,ØUGV1,,,/C,N,STATICS $
235  ØFP        ØUGV1,ØPG1,ØQG1,,,//V,N,CARDNØ $
236  ALTER      n10,n11 $ (where n10 = DMAP statement number of CØND LBLØFP,CØUNT and
                                 n11 = DMAP statement number of ØFP just before LABEL DPLØT)
237  ALTER      n12,n13 $ (where n12 = DMAP statement number of CØND P2,JUMPPLØT and
                                 n13 = DMAP statement number of REPT LØØPTØP,360)
238  ALTER      n14,n15 $ (where n14 and n15 are the DMAP statement numbers of LABEL ERRØR2
                                 and the PRTPARM module immediately following it, respectively)
     ALTER      n16,n17 $ (where n16 and n17 are the DMAP statement numbers of LABEL ERRØR4
                                 and the PRTPARM module immediately following it, respectively)
239  ENDALTER
240  CEND
241  TITLE = PHASE TWØ
242  BEGIN BULK
```

	1	2	3	4	5	6	7	8	9	10
243	DMI	KGG	0	6	1	2		3	3	
244	DMI	KGG	1	1	0.0					
245	DMI	PGT	0	2	1	2		3	1	
246	DMI	PGT	1	1	0.0					
247	SPØINT	1	THRU	3						
248	ENDDATA									

Table 6. Comments for Phase 2 Data Deck.

Card No.	Refer to Table 5 for input cards described below.
204	Rigid Format 1, Static Analysis, will be used for this problem.
205	Insert the following statement after DMAP statement No. 1.
206	Define the parameter TRUE = -1.
207	Delete the DMAP statements associated with the preparation of the Element Connection Table and structure plots (module GP2 thru LABEL P1).
208	Delete the DMAP statements associated with matrix assembly (PARAM just before TA1 thru LABEL LBL11A).
209	Insert the DMAP module INPUTT1 to read the partitioning vector, the stiffness matrix, and the load vector from User Tape 1. These matrices have been renamed E01, KGG01, and PG01, respectively. The user must arrange to have the tape mounted that was prepared at the end of Phase 1 run on substructure 1 copied to a file designated as INP1.
210	Insert the module MERGE to change the a-set size of the stiffness matrix from Phase 1 to g-size for Phase 2, and designate the output as KGGT01. In this particular case, no change will take place, since the a-size from Phase 1 is the same as the g-size in Phase 2.
211	Insert the module ADD to add the null matrix KGG, defined in the Bulk Data Deck, to KGGT01, and designate the output as KT01.
212	Insert the module EQUIV to equivalence KT01 to KGG.
213	Insert the module MERGE to change the a-size of the load vector from Phase 1 to g-size for Phase 2, and designate the output as PGT01. In this case, no change in size will take place.
214	Insert the module ADD to add the null matrix PGT, defined in the Bulk Data Deck, to PGT01, and designate the output as PT01.
215	Insert the module EQUIV to equivalence PT01 to PGT.
216	Insert the module INPUTT1 to read the partitioning vector, the stiffness matrix, and the load vector from User Tape 2. These matrices which were generated for substructure 2 in Phase 1 are redesigned as E02, KGG02, and PG02, respectively. The user must arrange to have the tape mounted that was prepared at the end of the Phase 1 run for substructure 2 copied to a file designated as INP2.

(Continued)

Table 6. Comments for Phase 2 Data Deck (continued).

Card No.	Refer to Table 5 for input cards described below.
217	Insert the module MERGE to change the stiffness matrix for substructure 2 from a-size in Phase 1 to g-size in Phase 2 and designate the output as KGGT02.
218	Insert the module ADD to add the stiffness matrix for substructure 2 to the stiffness matrix for substructure 1, and designate the output as KT02.
219	Insert module EQUIV to equivalence KT02 to KGG. The matrix KGG now represents the stiffness matrix for the pseudostructure, and will be used for input to Phase 2.
220	Insert the module MERGE to change the load vector from a-size in Phase 1 to g-size in Phase 2.
221	Insert the module ADD to add the loads applied to substructure 2 to the load vector for substructure 1, and designate the output as PT02.
222	Insert the module EQUIV to equivalence PT02 to PGT.
223	Delete the DMAP statements associated with the Grid Point Singularity Processor (CØND LBL4,GENEL thru LABEL LBL4).
224	Delete the SSG1 module.
225	Insert the module SSG1 with the calling sequence modified to remove parts not associated with directly applied loads. Since, for this particular problem, all loads were applied in Phase 1, there will be no output from SSG1.
226	Insert the module ADD to combine the load vector from Phase 2 with the load vectors generated in Phase 1, and designate the output as PGX.
227	Insert the module EQUIV to equivalence PGX to PG. The data block PG now includes all loads from both Phase 1 and Phase 2, and will be used as input to Phase 3.
228	Delete data recovery and ØFP modules (the first SDR2 thru the ØFP just before XYTRAN).
229	Insert the module ØUTPUT1 to rewind User Tape 3 and place the label USERTP3 on this file. The user must arrange a third file allocated which is designated as INPT. (It is presumed the INPT file will be copied to a tape at the end of the job.)
230	Insert the module PARTN to separate that part of the solution vector UGV associated with substructure 1, and designate the output as ULV01.

(Continued)

Table 6. Comments for Phase 2 Data Deck (continued).

Card No.	Refer to Table 5 for input cards described below.
231	Insert the module ØUTPUT1 to write the partition of the solution vector associated with substructure 1 on User Tape 3.
232	Insert the module PARTN to separate that part of the solution vector associated with substructure 2, and designate the output as ULV02.
233	Insert the module ØUTPUT1 to write that part of the solution vector associated with substructure 2 on User Tape 3. This will place the solution vectors for both substructures on User Tape 3. (A second tape could be used for the solution vector for substructure 2 by changing the DMAP statement for ØUTPUT1.)
234	Insert the module SDR2 with the calling sequence modified to remove those parts associated with element output.
235	Insert the module ØFP with the calling sequence modified to remove those parts associated with element output.
236	Remove ØFP and additional DMAP statements (CØND LBLØFP,CØUNT thru the ØFP just before LABEL DPLØT).
237	Remove the DMAP statements associated with the preparation of the deformed structure plots (CØND P2,JUMPPLØT thru REPT LØØPTØP,360).
238	Remove the statements associated with ERRØR2 and ERRØR4.
243, 244	DMI cards used to define the null matrix KGG.
245, 246	DMI cards used to define the null matrix PGT.
247	Definition of the three scalar points for the pseudostructure.

Table 7. Data Deck for Phase 3, Substructure 1.

```
NASTRAN   FILES = (INPT,ØPTP)
ID        PHASE,THREE $ SUBSTRUCTURE 1
TIME      2
APP       DISP
SØL       1,9
ALTER     n1,n2 $ (where n1 = DMAP statement number of module GP3 and
                         n2 = DMAP statement number of LABEL LBL9)
INPUTT1   /,,,,/C,N,-1/C,N,0/C,N,USERTP3 $
INPUTT1   /ULV,,,,/C,N,0 $
ALTER     n3,n4 $ (where n3 = DMAP statement number of CØND LBL8,REPEAT and
                         n4 = DMAP statement number of LABEL LBL8)
ALTER     n5,n6 $ (where n5 = DMAP statement number of JUMP FINIS and
                         n6 = DMAP statement number of LABEL FINIS)
ENDALTER
    (Include Restart Dictionary from Phase 1)
CEND
TITLE = PHASE THREE - SUBSTRUCTURE 1
DISP = ALL
ELFØRCE = ALL
ØLØAD = ALL
SPCFØRCE = ALL
BEGIN BULK
    (No Bulk Data)
ENDDATA
```

Table 8. Comments for Phase 3, Substructure 1 Data Deck.

Card No.	Refer to Table 7 for input cards described below.
304	Rigid Format 1, Static Analysis, will be used for this problem.
305	Delete all parts of the rigid format, except the data recovery modules (GP3 thru LABEL LBL9).
306	Insert module INPUTT1 to rewind and check the label on User Tape 3. The user must arrange to have the tape mounted that was prepared at the end of the Phase 2 run copied to a file designated as INPT.
307	Insert module INPUTT1 to read the solution vector for substructure 1 from User Tape 3. The solution vector is designated as ULV for input to module SDR1.
308 } 309 }	Remove additional DMAP statements not associated with data recovery operations (CØND LBL8,REPEAT thru LABEL LBL8 and JUMP FINIS thru LABEL FINIS).
311	Insert the Restart Dictionary punched during the Phase 1 run of substructure 1. The user must arrange to have the checkpoint tape from the Phase 1 run for substructure 1 copied to a file ØPTP for the restart.
314	Request printed output for all displacements of substructure 1.
315	Request printed output of forces for all elements in substructure 1.
316	Request printed output of the load vector for substructure 1. In this particular case, no output will result because no loads were applied to substructure 1.
317	Request printed output for all nonzero single-point forces of constraint on substructure 1.
318	Beginning of Bulk Data Deck.
319	No bulk data cards should be included in the Phase 3 run. However, the BEGIN BULK and ENDDATA cards must be present.
320	End of NASTRAN Data Deck.

Table 9. Data Deck for Phase 3, Substructure 2

```
350a NASTRAN   FILES = (INPT,ØPTP)
350b ID        PHASE,THREE $ SUBSTRUCTURE 2
351  TIME      2
352  APP       DISP
353  SØL       1,9
354  ALTER     n1,n2 $ (where n1 = DMAP statement number of module GP3 and
                              n2 = DMAP statement number of LABEL LBL9)
355  INPUTT1   /,,,,/C,N,-1/C,N,0/C,N,USERTP3 $
356  INPUTT1   /ULV,,,,/C,N,1 $
357  ALTER     n3,n4 $ (where n3 = DMAP statement number of CØND LBL8,REPEAT and
                              n4 = DMAP statement number of LABEL LBL8)
358  ALTER     n5,n6 $ (where n5 = DMAP statement number of JUMP FINIS and
                              n6 = DMAP statement number of LABEL FINIS)
359  ENDALTER
360      (Include Restart Dictionary from Phase 1)
361  CEND
362  TITLE = PHASE THREE - SUBSTRUCTURE 2
363  DISP = ALL
364  ELFØRCE = ALL
365  ØLØAD = ALL
366  SPCFØRCE = ALL
367  BEGIN BULK
368      (No Bulk Data)
369  ENDDATA
```

Table 10. Comments for Phase 3, Substructure 2 Data Deck.

Card No.	Refer to Table 9 for input cards described below.
355	Insert module INPUTT1 to rewind User Tape 3. The user must arrange to have the tape mounted that was prepared at the end of the Phase 2 run copied to a file, INPT, if it is not already available as a result of the previous run on substructure 1.
356	Insert module INPUTT1 to skip over the solution vector for substructure 1 on User Tape 3, and read the solution vector for substructure 2.
365	The request for printed output of the load vectors will show nonzero loads applied to grid points 3 and 4.

Table 11. Instructions for Modified Phase 2 Data Deck.

1. Remove card 116, SPC set selection for Phase 1 substructure 1 and request SPC set 201 after card 241.
2. Replace card 118 as shown in Table 12 to redefine the a-set for substructure 1.
3. Replace cards 121 and 122 with cards 121, 122, and 122a shown in Table 12 to redefine the partitioning vectors for substructure 1.
4. Card 128 is not required, SPC set definition for substructure 1 (see item 1 above).
5. Remove cards 165 and 166, SPC and load set selection for Phase 1, substructure 2 (see also item 1 above). Select LØAD set 202 and place after card 241.
6. Replace card 168 as shown in Table 12 to redefine the a-set for substructure 2.
7. Replace cards 172 and 173 with cards 172, 173, and 173a shown in Table 12 to redefine the partitioning vectors for substructure 2.
8. Cards 174, 175, and 182 are not required, load definition and SPC definition for substructure 2 (see item 1 above).
9. Replace cards 243 and 245 as shown in Table 12 to conform to new size for pseudostructure.
10. Insert the cards 246a and 246b as shown in Table 12 in the Bulk Data Deck for Phase 2 for definition of the loading condition and boundary condition.
11. Replace card 247 as shown in Table 12 to modify the definition of the pseudostructure to contain 12 scalar points.

Table 12. New Data for Modified Phase 2

	1	2	3	4	5	6	7	8	9	10
118	ASET1	126	1	3						
121	DMI	E1	0	2	1	1		12	1	
122	DMI	E1	1	1	1.0	1.0	1.0	1.0	1.0	+E11
122a	+E11	E1	1.0							
168	ASET1	126	3	4	5					
172	DMI	E2	0	2	1	1		12	1	
173	DMI	E2	1	4	1.0	1.0	1.0	1.0	1.0	+E21
173a	+E21	E2	1.0	1.0	1.0	1.0				
243	DMI	KGG	0	6	1	2		12	12	
245	DMI	PGT	0	2	1	2		12	1	
246a	SLØAD	202	5	1000.	8	1000.				
246b	SPC1	201		1	2	11				
247	SPØINT	1	THRU	12						

Table 13. Phase 1 Normal Modes Analysis Data Deck.

```
NASTRAN   FILES = (INPT,NPTP)
ID        PHASE,ØNE $ NØRMAL MØDES
TIME      2
CHKPNT    YES
APP       DISP
SØL       3,0
ALTER     n1,n2 $ (where n1 = DMAP statement number of CØND LBL6,REACT and
                         n2 = DMAP statement number of LABEL P2)
ØUTPUT1   E10,KAA,MAA,,//C,N,-1/C,N,0/C,N,USERTP1 $
ENDALTER
CEND
   (Case Control Deck)
BEGIN BULK
   (Bulk Data Deck)
ENDDATA
```

Table 14. Phase 2 Normal Modes Analysis Data Deck.

```
NASTRAN   FILES = (INPT,INP1,INP2)
ID        PHASE,TWØ $ NØRMAL MØDES
TIME      2
APP       DISP
SØL       3,0
ALTER     n0 $ (where n0 = DMAP statement number of the BEGIN statement)
PARAM     //C,N,NØP/V,N,TRUE=-1 $
ALTER     n1,n2 $ (where n1 = DMAP statement number of module GP2 and
                         n2 = DMAP statement number of module SMA3)
INPUTT1   /E01,KGG01,MGG01,,/C,N,-1/C,N,1/C,N,USERTP1 $
MERGE,    ,,,KGG01,E01,/KGGT01 $
ADD       KGG,KGGT01/KT01 $
EQUIV     KT01,KGG/TRUE $
MERGE,    ,,,MGG01,E01,/MGGT01 $
ADD       MGG,MGGT01/MT01 $
EQUIV     MT01,MGG/TRUE $
INPUTT1   /E02,KGG02,MGG02,,/C,N,-1/C,N,2/C,N,USERTP2 $
MERGE,    ,,,KGG02,E02,/KGGT02 $
ADD       KGG,KGGT02/KT02 $
EQUIV     KT02,KGG/TRUE $
MERGE,    ,,,MGG02,E02,/MGGT02 $
ADD       MGG,MGGT02/MT02 $
EQUIV     MT02,MGG/TRUE $
ALTER     n3,n4 $ (where n3 = DMAP statement number of CØND LBL4,GENEL and
                         n4 = DMAP statement number of LABEL LBL4)
ALTER     n5,n6 $ (where n5 = DMAP statement number of module SDR2 and
                         n6 = DMAP statement numbber of LABEL P2)
ØUTPUT1   LAMA,,,,//C,N,-1/C,N,0/C,N,USERTP3 $
PARTN     PHIG,,E01/,PHIA01,,/C,N,1 $
ØUTPUT1   PHIA01,,,,//C,N,0/C,N,0/C,N,USERTP3 $
PARTN     PHIG,,E02/,PHIA02,,/C,N,1 $
ØUTPUT1   PHIA02,,,,//C,N,0/C,N,0/C,N,USERTP3 $
```

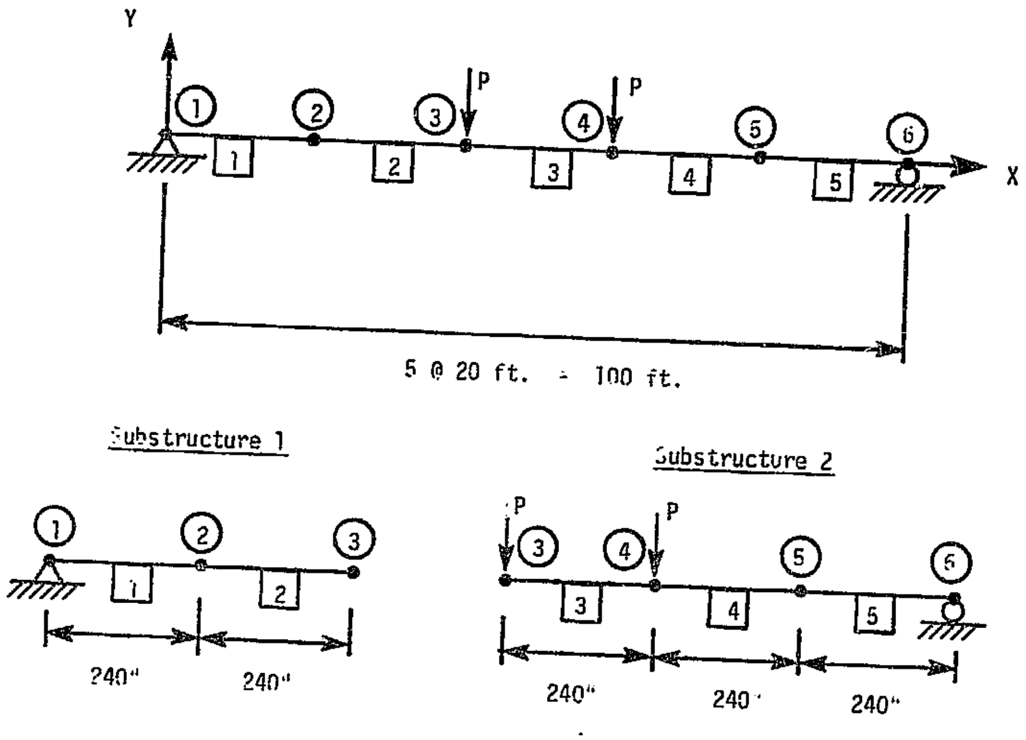
(Continued)

Table 14. Phase 2 Normal Modes Analysis Data Deck (continued).

```
SDR2      CASECC,CSTM,MPT,DIT,EQEXIN,SIL,,,BGPDT,LAMA,QG,PHIG,,/
          ,ØQG1,ØPHIG,,,/C,N,REIG $

ØFP       ØPHIG,ØQG1,,,,//V,N,CARDNØ $

ALTER     n7,n8 $ (where n7 and n8 are the DMAP statement numbers of LABEL ERRØR1 and
                   the PRTPARM module immediately following it, respectively)

ENDALTER

CEND

   (Case Control Deck)

BEGIN BULK

   (Bulk Data Deck)

ENDDATA
```

Table 15. Phase 3 Normal Modes Analysis Data Deck.

```
NASTRAN   FILES = (INPT,ØPTP)
ID        PHASE,THREE $ NØRMAL MØDES
TIME      2
APP       DISP
SØL       3,0
ALTER     n1,n2 $ (where n1 = DMAP statement number of module GP3 and n2 = DMAP statement
                          number of the ØFP module just prior to the SDR1 module)
INPUTT1   /LAMA,,,,/C,N,-1/C,N,0/C,N,USERTP3 $
INPUTT1   /PHIA,,,,/C,N,0 $
ALTER     n3,n4 $ (where n3 = DMAP statement number of JUMP FINIS and
                     n4 = DMAP statement number of LABEL FINIS)
ENDALTER
   (Include Restart Dictionary from Phase 1)
CEND
   (Case Control Deck)
BEGIN BULK
   (No Bulk Data)
ENDDATA
```



② Grid Point Numbers

3 Element Numbers

E = 30 x 10^6 psi

I = 500 in^4

P = 1000 lbs

Figure 1. Manual substructuring problem.

1.10.2 Automated Multi-Stage Substructuring

Large and complex structural analysis problems can be solved for static and dynamic response and/or normal mode shapes using the automated multi-stage substructuring features of NASTRAN. As with all substructuring approaches, the user subdivides the intended model into a set of smaller, more elementary partitions called basic substructures. The components of the whole structure can be modeled independently, checked for accuracy, and then assembled automatically all at once or in stages to form a composite model representing the whole structure for final solution.

In order to effectively employ this automated substructuring capability of NASTRAN for static and normal modes analyses, the user should gain an overall understanding of the basic program design concepts, the data base on which it operates, and the control functions provided. These topics are discussed in the sections which follow. Suggestions, recommendations, and cautions to be observed when using automated substructuring are presented in Section 1.10.2.6.

A detailed description of the substructuring control cards and a summary of pertinent bulk data cards is provided in Section 2.7 of this manual. A detailed description of each of these bulk data cards is included alphabetically along with all other bulk data cards in Section 2.4. The basic design concepts used in developing this automated substructuring capability are described below. The theory is presented in Section 4.6 of the Theoretical Manual.

1.10.2.1 Basic Concepts

Automated substructuring analysis is available for use with NASTRAN Rigid Fromats 1, 2, 3, 8, and 9. This provides capability for static analysis, static analysis with inertial relief for unsupported structures, and normal modes, frequency response, and transient response analyses. The capability allows an unlimited number of substructures to be combined and/or reduced in any sequence desired. Each substructure is represented by its mass, stiffness, and damping matrices. A reduction in size or condensation of these matrices is accomplished using the Guyan reduction technique or reduction to normal or complex modal coordinates.

Although the NASTRAN substructuring system may be used for small and moderate size problems, several features are available to accommodate very large problems. The most important of these features is the automated data base management system used to maintain the Substructure Operating

File (SØF) on which all pertinent matrix and substructural loading data and associated control files are stored. This SØF carries all the information needed from run to run throughout a substructuring analysis.

Processing automated substructuring analyses is subdivided into three phases similar to those described earlier for manual substructuring. The usual analysis proceeds as follows. First, several separate Phase 1 executions are performed, one for each basic substructure. Second, one or more Phase 2 executions may be performed. In a Phase 2 run, any number of substructure reductions and/or combinations, resulting in higher level (meaning more complex) pseudostructures, may be performed. Phase 2 processing may be halted at any stage of model assembly and restarted in a subsequent Phase 2 execution. The results at each step in the operation are stored on the SØF so as to be available for subsequent execution. The final steps of a Phase 2 operation would be the solution step for the highest level structure and the data recovery steps with limited output capability (displacements, forces of constraint, modal energies, and applied loads only) for any lower level substructure. Complete and detailed data recovery for the basic substructures must be obtained by separate Phase 3 executions, one for each basic substructure. This level of data recovery may inlcude any or all of the NASTRAN output normal for a non-substructure analysis.

Automated substructuring allows each basic substructure to be defined independently. This concept is represented by three key features of the system.

1. There are no restrictions as to duplication of grid point or element identification numbers, load sets, individual coordinate systems, etc. All data for a given substructure is associated with an assigned unique name for that structure. The only data restriction is one of proper modeling, i.e., common boundaries require grid points to be located at the same point in space for each connecting substructure.

2. No substructure may appear as a component of another substructure more than once; and no degrees of freedom within a substructure may be connected ("combined") to other degrees of freedom in that same substructure except by multipoint constraints imposed at the solution step operation.

3. All pertinent substructure data are stored on the SØF, an expandable direct access file. This file may be selectively edited and/or dumped to tape and transmitted to another user who may have need for the data. Provision is made for automated tape conversion among

CDC, IBM, UNIVAC and DEC VAX computers to facilitate such data transmittal between different users. Use of this file is described in Section 1.10.2.4.

Control of the automated substructuring system is obtained through the use of linguistic commands, similar to those of Case Control. These commands are placed in the Substructure Control Deck shown in Figure 2. This Substructure Control Deck is situated between the Executive Control and Case Control Decks.

Each substructure control command is automatically translated into appropriate DMAP ALTER cards to augment the requested Rigid Format sequence. The user may also include his own DMAP ALTER commands, or he may modify a previously defined DMAP sequence. A description of how the user may interface with this NASTRAN-generated substructuring DMAP is presented in Section 2.7.2. Listings of the DMAP ALTERs generated by each substructure command are presented in Section 5.9. Descriptions of the corresponding modules provided for substructuring are found in the NASTRAN Programmer's Manual.

1.10.2.2 Substructure Operations and Control Functions

User control of the automated multi-stage substructuring system is obtained via the Substructure Control Deck commands. The key terms used to describe these commands and their functions are defined in Table 16. A summary of the substructuring command options is presented in Table 17. Some of these commands require specific bulk data cards which are listed for easy reference in Table 18. The user should also refer to Section 2.7 for a complete description of the Substructure Control Deck commands and to Section 2.3 for detailed descriptions of the corresponding bulk data cards.

The operation and control functions of automated substructuring analysis are best illustrated and explained using the "tree" structure presented in Figure 3. This figure defines the geneology of all the component substructures used in building a final model. Basic substructures are created at the Phase 1 level. Substructures "A," "B," and "E" are shown in solid boxes indicating they were formed from actual data deck submittals and are physically different models. The dotted boxes are called "image" substructures and are the result of an EQUIVALENCE operation rather than an actual Phase 1 data deck submittal. The EQUIVALENCE operation defines a new substructure which is a duplicate of an existing substructure and automatically creates all equivalent lower level component substructures. Thus, space is saved on the data files by eliminating storage of redundant matrix data. A four-bladed propeller, for example, could be seen to consist of four

identical components and, hence, only one need by explicitly modeled. The other three blades could be defined solely by using the EQUIVALENCE command.

The image substructures exist in name only. Note in Figure 3 that the names of the image structures are identical to the equivalent parent structure, with the exception of a prefix character. The new names would be created automatically by NASTRAN with the use of the PREFIX subcommand to EQUIVALENCE. These new prefixed names would then be used to reference the appropriate component substructure as if it were created independently.

Note, the term "lower level" refers to the less complex of the component substructures which are used to create a higher level, or more complex substructure.

From the user point of view, all substructures shown in Figure 3, with either solid or dotted boxes, are separate and distinct substructures. They may have different applied loads, boundary conditions, and responses. For example, though only A, B, and E represent actual Phase 1 executions, Phase 3 data recovery executions may be made for A, B, E, XA, XB, YA, YB, YXB, and YE, each of which generally would have different results.

The CØMBINE command (see Table 17) with its numerous subcommands, offers flexibility in the assembly of substructures into a higher level substructure. The CØMBINE capability allows component substructures to be translated, rotated, and/or symmetrically transformed via mirror image transformation for proper positioning in space.

For example, the right wing of an aircraft is first modeled and an EQUIVALENT operation is performed to define an identical duplicate wing. Then, in the CØMBINE operation, a SYMTRANSFØRM is applied so that the wing now appears as the actual left wing (a mirror image of the right wing), and a TRANSFØRM is applied to properly position it on the left side of the aircraft. Caution is advised in that the symmetry transformation (SYMTRAN) is always applied to the component in its own basic coordinate system before the usual translation and rotation (TRANS) for final positioning (see Section 4.6 of the Theoretical Manual).

The REDUCE command causes a Guyan reduction to be performed on an existing substructure. The user specifies which degrees of freedom are to be retained using the BDYC and BDYS (or BDYS1) bulk data cards provided. The degrees of freedom retained are all called boundary degrees of freedom although they all need not ever appear on the boundary with another substructure. Obviously, all degrees of freedom eventually needed for boundary connections must be retained, i.e., they must not be reduced out. However, care must be taken to retain in this boundary set

all the appropriate degrees of freedom needed to represent the dominant displacement patterns for accurate calculation of eigenvalues and eigenvectors for normal modes analyses.

The MREDUCE and CREDUCE commands provide a modal synthesis capability to automated multi-stage substructuring. With these commands the user defines boundary degrees of freedom to identify degrees of freedom retained as physical coordinates. The remaining degrees of freedom are replaced by a smaller set of normal (MREDUCE) or complex (CREDUCE) generalized modal coordinates. MREDUCE may be used when real symmetric mass and stiffness matrices are used to define the model. CREDUCE provides a general modal reduction capability when damped modes are desired or complex or unsymmetric matrices are present.

The user may also define constraints for the structure to be applied only for the purpose of calculating the modes. BDYC and BDYS (or BDYS1) bulk data cards are used to define these degrees of freedom and are requested by the subcommand FIXED.

Note that for both the REDUCE and MREDUCE substructure commands, the damping matrices, B and K4, and the load vectors, P, are transformed to the reduced set of coordinates. The reduced substructures may be processed with any of the other substructure operations. However, substructures generated with the complex modal reduction, CREDUCE, may not be processed with any commands requiring real arithmetic, namely REDUCE, MREDUCE, or SØLVE with Rigid Formats 1, 2, 3, or 9.

As many EQUIVALENCE, CØMBINE, REDUCE, MREDUCE, or CREDUCE commands as desired may be used in one or more Phase 1 or Phase 2 executions. However, only one SØLVE command is allowed in any single Phase 2 execution, and the SØLVE command is not allowed in Phase 1 executions. As indicated in the definitions of Table 1, the SØLVE command requests a solution for structural response to applied static loads (Rigid Formats 1 and 2), the calculation of normal modes (Rigid Format 3), or structural response to frequency dependent or time dependent loads (Rigid Formats 8 and 9) of the substructure named in the command.

The RECØVER command is used in Phase 2 to recover the solution data for successively lower level substructures. Only the displacements, forces of constraint, modal energies, and applied loads can be selectively output for any component substructure during these Phase 2 operations. The BRECØVER command is then used in a Phase 3 execution to obtain all the detail response output normally provided by NASTRAN for each desired <u>basic</u> substructure. The command, MRECØVER, is used to recover mode shape data for modal reduced substructures.

Using the PLØT command, only undeformed plots may be requested in a Phase 2 execution. Deformed plots can only be obtained from a Phase 3 execution.

The user controls each step in the analysis by specifying the appropriate commands to be executed and the substructure names, such as A, B, YC, etc. (see Figure 3), of each substructure to be used in that step.

To reduce the potential for input error and to simplify the bookkeeping tasks, all specific references to loadings and grid points for connection, boundary sets, and constraints, etc. are made with respect to the basic substructure name only. For these reasons, no component substructure may be used more than once while building the solution structure. That is, every component named in any substructure must be unique. If the same component substructure is to be used more than once, e.g., identical components are to be used to create the full model, the EQUIVALENCE operation should be used as described earlier to assign unique names to all substructures comprising that component.

Substructure names are allowed no more than eight alphanumeric characters. Notice in the EQUIVALENCE operation shown in Figure 3, the required subcommand PREFIX generates an additional character which is placed ahead of the existing name as a prefix to the parent substructure name. Care must be taken with successive EQUIV operations to monitor the growth of image substructure names so as not to exceed the eight-character limit. If the limit is exceeded, the right-most character will be truncated. Therefore, it is possible to inadvertently create duplicate substructure names as more prefixes are added. It is recommended, therefore, that the entire tree structure for the analysis be prepared ahead of time to help avoid these problems. This preplanning also will be an invaluable aid to the task of data preparation and proper sequencing of the individual steps in the analysis.

1.10.2.3 Input Data Checking and Interpretation of Output

The automated substructuring system provides several methods for input data checking, diagnostic output, and substructure-oriented data output.

A principal facility for input data checking is the RUN=DRY command. This option allows the user to validate the command structure and data without actually performing the more time consuming matrix operations. Assuming the input is found to be consistent, the run may be resubmitted with the RUN=GØ option to complete the matrix processing.

Also available is a RUN=STEP option (the default option) which first checks the data and then executes the matrix operations one step at a time. If errors are detected in the data, the matrix operations are skipped and the remainder of the processing sequence is executed as a DRY run only.

The user also is allowed to process only selected matrix data. If, for example, after having assembled the solution structure, new loading conditions are to be added or normal modes are desired but the mass matrix is not available, the necessary sequence of matrix operations can be requested using the RUN=GØ option to process the new load or mass matrix data only. The ØPTIØNS command, described in Section 2.7, causes selective processing of mass (M), damping (B) or (K4), stiffness (K), or load (P) data only. The PA option (load append) is used when new Phase 1 load vectors are to be added to the set of existing load vectors. Note that when using the ØPTIØNS command, if existing substructure data items are to be recreated (see Table 19), the old data must be removed using the EDIT or DELETE commands as described in the next section. This is necessary because only one item of a given type may be allowed on the SØF for any particular substructure.

All the relevant substructuring data generated by the program may be displayed with the ØUTPUT command described in Section 2.7. The CØMBINE, REDUCE, MREDUCE, and CREDUCE operations involve specification of grid point and degree of freedom data related to the basic substructures involved. The automatically generated or manually specified connectivities are critical to the CØMBINE operation. Using these output options, the information can be obtained to explicitly verify all connectivities. The REDUCE, MREDUCE, and CREDUCE operations require the user to specify the degrees of freedom to be retained. These also are identified by basic substructure grid point numbers. If desired, these same output options can be used to obtain lists of all the retained degrees of freedom of the resulting pseudostructure to help verify the resulting model. The following paragraphs describe examples of the possible output that can be requested.

The table shown below may be used to verify all substructure connectivities. This, and the other examples of diagnostic output to be described later, are reporductions of actual problem output requested under the CØMBINE command used to create a pseudostructure named WINDMILL from component substructures RING and VANR.

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SUMMARY ØF PSEUDØSTRUCTURE CØNNECTIVITIES

INTERNAL PØINT NØ	INTERNAL DØF NØ	DEGREES ØF FREEDØM	RING	VANR
34	67	12	RING 146	
35	69	12	RING 147	
36	71	12	RING 148	
37	73	12	RING 103	VANE 1
38	75	12	RING 106	VANE 2
39	77	12	RING 109	VANE 3
50	79	12		VANE 13
41	81	12		VANE 14

The column heading "INTERNAL PØINT NØ" references the equivalent of internally generated "grid points" for the resulting pseudostructure. "INTERNAL DØF NØ" references the internally sequenced first degree of freedom (row or column number) in the matrices of WINDMILL for the designated internal grid point. "DEGREES ØF FREEDØM" references the component degrees of freedom in the global coordinate system of the assembled structure associated with the internal grid point. In the example above, the following may be observed:

1. Degrees of freedom 1 and 2 from grid point 109 of basic substructure RING and grid point 3 of basic component VANE in substructure VANE are connected and assigned to internal point 39 of pseudostructure WINDMILL.
2. Displacement components 1 and 2 at internal point 39 are the 77th and 78th degrees of freedom for the matrices of WINDMILL.

Note that only basic substructure names appear in association with grid points. In this example, RING and VANR are the substructures referenced by the CØMBINE command. VANR exists as a higher level substructure with VANE as the basic substructure.

Substructure items EQSS and BGSS, which are created by the CØMBINE or REDUCE operations, are helpful in checking the results of these substructure commands. They are stored along with the other items on the SØF (see Table 19) and can be accessed at any time with the SØFPRINT command. The display of these items, however, is normally requested by the ØUTPUT subcommand of either the CØMBINE, REDUCE, MREDUCE, or CREDUCE commands at the time of their execution.

The EQSS item provides data for each basic substructure relating external or basic substructure grid point numbers to pseudostructure internal grid point numbers. In the example shown below, degrees of freedom 1 and 2 of grid point 102 of basic substructure RING have been assigned to internal grid point 2 of pseudostructure WINDMILL.

EQSS ITEM FØR SUBSTRUCTURE WINDMILL CØMPØNENT RING

GRID PØINT ID	INTERNAL PØINT NØ	CØMPØNENT DØF
102	2	12
105	4	12
108	6	12
111	8	12
114	11	12
117	13	12
120	15	12
123	17	12
126	20	12
129	22	12
132	24	12
135	26	12
138	29	12
141	31	12
144	33	12
147	35	12

In addition to the above data for each basic substructure, the EQSS item also contains summary data for the resultant pseudostructure. A sample is shown below.

EQSS ITEM - SCALAR INDEX LIST FOR SUBSTRUCTURE WINDMILL

INTERNAL PØINT ID	INTERNAL SIL ID	CØMPØNENT DØF
2	3	12
5	9	12
8	15	12
11	21	12
14	27	12
17	33	12
20	39	12
23	45	12
26	51	12
29	57	12
32	63	12
35	69	12

In the above table, the relationships of the internal grid point numbers to the internal degree of freedom numbers (referenced as "INTERNAL SIL ID") and to the component degrees of freedom are defined for pseudostructure WINDMILL. The internal degrees of freedom are referenced as a Scalar Index List (SIL) because all substructure problem degrees of freedom are converted to scalar points for purposes of Phase 2 processing. If desired for special purposes, therefore, these internal degrees of freedom may be referenced as scalar points for use with any of the nonsubstructuring Bulk Data cards to be input to the SØLVE step operations in Phase 2.

The EQSS items and the summary of pseudostructure connectivities table are related. For example, by cross referencing each table it can be seen that internal grid point 35 of substructure WINDMILL has degrees of freedom 1 and 2 assigned to it. These degrees of freedom numbers in the SIL list are 69 and 70, respectively, and these degrees of freedom come from grid point 147 of basic substructure RING.

Special treatment is required for the EQSS item for substructures which are modal reduced. For example, if basic substructure A is reduced to MA using MREDUCE or CREDUCE, the EQSS for MA indicates that pseudostructure MA has two component substructures, A and MA. The EQSS for component A contains the boundary point definitions. The EQSS for component MA contains definitions for the newly created modal coordinates. Inertia relief coordinates are assigned Grid Point ID's of 1 through 6 to MA, and flexible mode coordinates are assigned GRID Point ID's of 101 through 100+N where N is the number of flexible modes used. Refer to Sections 4.6.2 and 18 of the Theoretical Manual and Section 2.7 of this manual for definitions of the modal coordinates.

The modal degrees of freedom of component substructure MA (both inertia relief and flexible mode coordinates) may be referenced for application of constraints in the SØLVE operation. They may also be referenced as boundary coordinates in subsequent reduction operations.

CØMBINE or reduction operations also create the BGSS item. A sample is shown below. The BGSS item contains internal grid point locations for the substructure model. In this example, the BGSS item displays all the internal point numbers for the pseudostructure WINDMILL along with its corresponding location coordinates in that pseudostructure's basic system. The "CSTM ID NØ" column indicates the existence (if any) of local coordinate systems associated with those internal points. If the entry is "0", the displacement components will be in that pseudostructure basic

BGSS ITEM FØR SUBSTRUCTURE WINDMILL

INTERNAL PØINT ID	CSTM ID NØ	C Ø Ø R D I N A T E S		
		X1	X2	X3
1	0	-0.500000E+01	0.100000E+02	0.E+00
2	0	-0.500000E+01	0.150000E+02	0.E+00
3	0	0.E+00	0.100000E+02	0.E+00
4	0	0.E+00	0.150000E+02	0.E+00
5	0	0.500000E+01	0.100000E+02	0.E+00
6	0	0.500000E+01	0.150000E+02	0.E+00
7	0	0.750000E+01	0.750000E+01	0.E+00
8	0	0.100000E+02	0.100000E+02	0.E+00
9	0	0.125000E+02	0.125000E+02	0.E+00
10	0	0.100000E+02	0.500000E+01	0.E+00

system. Otherwise, they will be in a local system which may be verified with the optional printout of the coordinate system transformations (a 3x3 matrix of direction cosines) as stored in the "CSTM" item for that pseudostructure.

Modal coordinates are indicated in the BGSS by a CSTM ID NØ of -1 and a coordinate location of X1 = 0.0, X2 = 0.0, and X3 = 0.0. The CSTM ID NØ of -1 is NASTRAN convention for a scalar point. Note that scalar points will never be combined with any other points using the automatic CØMBINE operation.

Another useful output item is the SUBSTRUCTURE ØPERATING FILE TABLE ØF CØNTENTS (TØC), as shown in Figure 4. In this figure, the substructure tree has been added to the TØC output to help visualize the sample problem. This output is obtained with the command: SØFPRINT TØC. The TØC lists by name all substructures that reside on the SØF, lists the current items available for each substructure, and provides a set of pointers which describe the hierarchy of substructure relationships. The SØF pointer scheme is described by defining the individual column headings shown in the TØC:

TYPE Defines the substructure type:

B - basic substructure

C - combined substructure

R - Guyan reduced substructure

M - real modal reduced substructure

CM - complex modal reduced substructure

Any of the above types will have prefix "I" if it is an image substructure resulting from an EQUIV operation.

SS Points to a substructure which is secondary to the current substructure. In the case where many secondary substructures have been EQUIVed to a single primary substructure, the SS entries form a chain starting with the primary substructure and ending with an SS pointer of zero.

PS Points to the substructure which is primary to the current substructure. PS is non-zero for secondary substructures only.

LL Points to a substructure at the next lower (simpler) level to the current substructure.

CS Points to a substructure which has been combined with the current substructure. The CS entries form a circular chain.

HL Points to the substructure at the next higher (complex) level to the current substructure.

All normal NASTRAN output for each basic substructure, primary or image substructure, is available via a Phase 3 execution. Also, certain output may be recovered in Phase 2 for any or all of the substructures in the solution structure's tree. However, this output is limited to displacements, applied loads, and forces of single-point constraint. The output requested in Phase 2 is labeled by both the pseudostructure and its component basic substructure names.

Some discussion of the forces of constraint, which may be requested as output in both Phase 2 and Phase 3, is required. The Phase 3 calculations for forces of constraint are computed in the normal NASTRAN convention (refer to Section 3.7 of the Theoretical Manual). In a Phase 2 execution, however, the forces of constraint include additional terms. The equations used for the calculations are shown below and are identified by rigid format application. In these equations, {Q} are the forces of constraint, {P} are the applied loads, {u} is the displacement vector, [K]

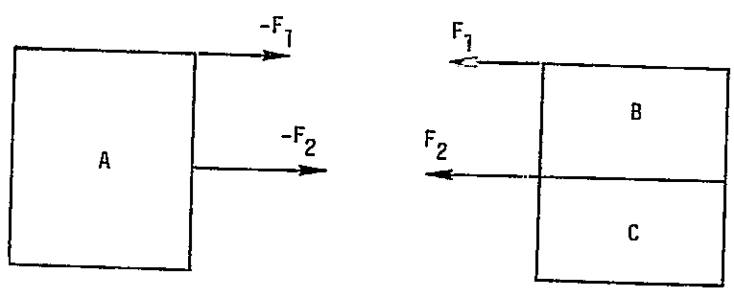
is the stiffness, [B] is the damping, [M] is the mass, ω^2 are eigenvalues from a real modes analysis, and ρ are complex eigenvalues from a complex modal reduction.

Rigid Format	Equation for Forces of Constraint
1 and 2	$\{Q\} = [K]\{u\} - \{P\}$
3	$\{Q\} = [K]\{u\} - [M][\omega^2]\{u\}$
3	$\{Q\} = [K]\{u\} + [B][\rho]\{u\} + [M][\rho^2]\{u\}$
8 and 9	$Q = [K]\{u\} + [B]\{\dot{u}\} + [M]\{\ddot{u}\} - \{P\}$

The force vectors {Q} contain all the terms due

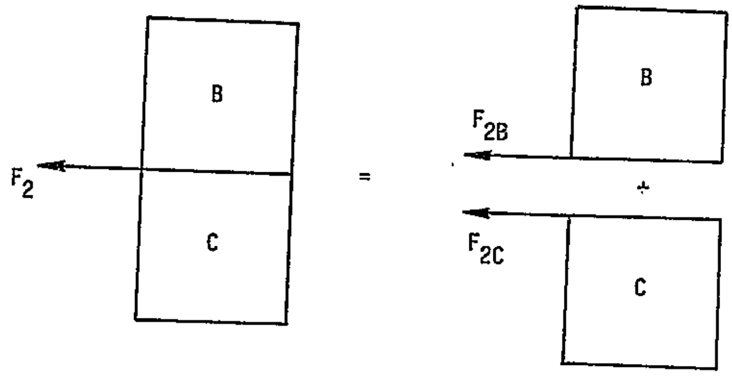
1. Inertia forces
2. Damping forces
3. Single-point constraints
4. Multipoint constraints
5. Forces transferred from other connected substructures
6. Residual forces due to computer round-off

The equations presented above for calculation of forces of constraint provide especially useful information, i.e., the forces of substructure interconnection as shown below.



Substructure A Substructure BC

Forces F_1 and F_2, recovered as forces of constraint for substructure A and for pseudostructure BC, represent the forces of interconnectivity. Force F_2 represents the sum of two component forces, one from each component substructure B and C, acting at their common grid point. The separate contributions to F_2 from each B and C may be determined by using the RECØVER command for the component substructures B and C individually, as shown below.



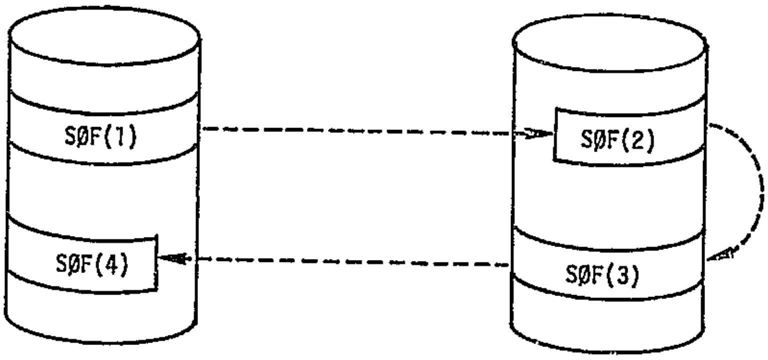
1.10.2.4 Substructure Operating File (SØF)

The data required for each basic substructure and for all subsequent combinations of substructures are stored on the Substructure Operating File (SØF). The SØF data are stored in direct access format on disk or drum during a NASTRAN execution. These data may also be stored on tape between runs for backup storage or for subsequent input to other computers. Schematic diagrams of data flow for each of the three phases of execution are given in Figure 5.

The SØF file, which contains the data items listed in Table 19, is used to communicate all required data between each phase of operation and between each step of the Phase 2 operation. Thus, the user is allowed to develop his analysis in separate steps without requiring the checkpoint/restart feature of NASTRAN. A Phase 1 run is required to build each basic substructure and place its data on the SØF prior to any Phase 2 reduction or combination using that substructure. Using that data, component pseudostructures may be assembled in stages from these basic substructures and added later to other component substructures already on the SØF file. Also, the same SØF may be used to build the data files for more than one solution structure at a time.

Once the final solution model is established, the solution may be obtained and results recovered for any level, component pseudo- or basic substructure. However, detail element stresses and element forces or support reactions specified with the basic substructure can be recovered only in Phase 3. These Phase 3 results may be recovered either by using the original data deck or by restarting from a checkpointed Phase 1 execution.

The SØF is structured as a single logical file used to store all data necessary for a complete multi-stage substructuring analysis. However, the SØF may actually reside on from one to ten physical files. These physical files would be chained together to form the single logical file for use in the analysis of larger problems. The figure below shows the basic arrangement of an SØF on disk or drum.



Each physical file comprising the SØF is a direct access file. These disk or drum files are not used by NASTRAN GINØ operations. NASTRAN treats them as external user files. In a substructure analysis, NASTRAN stores data on the SØF which must be saved from run to run. Therefore, it is the user's responsibility to maintain the physical files comprising the SØF from one execution to the next. For large disk files which may arise in some substructuring problems, it may be advisable to store the SØF on tape for backup protection between executions. The user should refer to the DUMP, RESTØRE, SØFØUT, and SØFIN commands for this capability or use operating system utilities.

The SØF declaration in the Substructure Control Deck is used to define the physical files which make up the SØF. See Section 2.7 for a complete description of the SØF declaration. An SØF composed of only one physical file which already exists would be declared as follows:

SØF(1)=SØF1,200,ØLD (CDC example)

A new SØF composed of three physical files could be declared as follows on the first execution with this particular SØF logical file:

SØF(1)=SØF1,200,NEW
SØF(2)=SØF2,200
SØF(3)=SØF3,400

The parameter "NEW" is never used again on any subsequent execution with this SØF. If it were used, all data on that SØF logical file would be lost. For example, to add a new physical file on a subsequent execution, simply add its declaration, i.e., SØF(4)=SØF4,600. Again, do not declare this as a "NEW" file or the whole logical SØF file will be re-initialized and all existing data will be lost. (Refer to the SØF command in Section 2.7 for machine dependent restrictions.)

All data stored on the SØF is accessed via the substructure name. For each substructure, various types of SØF data may be stored. These types of data are called items and are accessed via their item names. Thus, the substructure name and item name are all that is required to access any block of data on the SØF. The items which can be stored for any substructure are described in Table 19. The program automatically keeps track of the data, stores the data as it is created, and retrieves these data when required. The user's only responsibility is to maintain the file. It must be accessible by the system when needed. The user must remove items generated from data containing input errors and/or if that data is no longer needed for subsequent analyses. Also, data may be selectively stored on a backup tape for later retrieval, thus releasing needed space for subsequent operations.

1.10.2.5 The Case Control Deck for Automated Substructure Analyses

The Case Control Deck for substructuring analysis controls loading conditions, constraint set selection, output requests, and method of analysis just as in any non-substructuring analysis. However, in a substructuring analysis, there are very important relationships among the Case Control Decks to be input for each of the three Phases of substructuring. Compatibility among the substructuring phases must be maintained for load sets, constraint sets, and subcase definitions.

The following requirements must be satisfied by the Case Control Deck in Phase 1:

1. Constraint set selection (MPC, SPC) must be above the subcase level. That is, only one set of constraints is allowed in Phase 1 for all loading conditions.
2. One subcase must be defined for each loading condition which is to be saved on the SØF. The loading condition may consist of any combination of external static loads, thermal loads, element deformation loads, or enforced displacements. Loading conditions which are not saved on the SØF in Phase 1 cannot be used in any solution in Phase 2.

The Phase 2 Case Control Deck is exactly like the Case Control used in a non-substructuring analysis. Only the TITLE and BEGIN BULK cards are needed except when plots are requested or when there is a SØLVE command in the Substructure Control Deck. In this latter case, the subcase definitions, load and constraint set selections, etc. are used in the usual fashion to control the solution process.

Output requests in Case Control are honored only if there is a PRINT subcommand under the RECØVER command in the Substructure Control Deck. If a RECØVER command with a PRINT subcommand is used, the Case Control should be identical (except for output requests) to that used to obtain the solution being printed.

The following requirements must be satisfied by the Case Control Deck in Phase 3:

1. Constraint sets (MPC, SPC) must be identical to those used in Phase 1 for this substructure.

2. The subcase definition for load set IDs must be identical to those used in Phase 1 for this substructure including those for appended loads, if any. All load definitions must appear in the order generated.

3. The subcase definition for the Phase 3 output requests for solution vectors generated in Phase 2 must be merged with the above subcase definition for load set IDs. Note, the ØLØAD output requested in Phase 3 will correspond to the load factors defined during Phase 2 solution, not those defined by Phase 3 Case Control.

The number of Phase 3 subcases required is the maximum of those defined in either Phase 1 or Phase 2. All output requests will correspond to the Phase 2 subcase sequence, starting with the first subcase defined in Phase 3. It is essential to assign the same thermal and element deformation loadings to the same subcases in both Phase 1 and Phase 2 in order to provide the correct load correction data to the Phase 3 output processing of element forces and stresses.

1.10.2.6 User Aids for Automated Substructure Analyses

The following suggestions, recommendations, and cautions should be considered when using automated multi-stage substructuring. The automated substructuring capability offers the user flexibility in the performance of an analysis. To take advantage of this capability, it is recommended that the new user carefully review both the Theoretical and User's Manual sections on substructuring and execute the sample problem which is documented in the following Section 1.10.2.7.

Simulation Analyses - The user is advised to simulate large structural model analyses with simplified models using the substructuring system. Using this technique, all deck structures, including operational commands and control of the SØF, may be tested using small matrices at low cost. In addition, any special features such as user DMAP operations may be tested at this time.

Reduction - Generally, the most economical analyses may be performed using relatively small basic substructures or by performing significant reductions in Phase 1 (using ØMIT or ASET bulk data cards). When using Guyan reduction, either reduce most degrees of freedom (many more than half) or very few degrees of freedom (many less than half) if possible. Note that the resulting matrices are usually dense and, hence, may take up more space on the SØF than the original matrices.

When using modal reduction use the FIXED set to help approximate the expected solution mode shapes. Also, remember that when inertia relief shapes are requested, six shapes are created. However, if the problem is not fully three dimensional, some of these shapes may be null, and the resulting singularities must be accounted for in subsequent operations. Note that flexible mode shapes which introduce singularities, such as rigid body shapes at zero frequency, are automatically excluded from assignment to the reduced substructure. The rigid body shapes are not needed because the boundary points, by definition, must provide the rigid body description of the structure.

Load Append - In the event that additional new loading conditions are required, the LØDAPP (Load Append) features may be used. This feature, described in Section 2.7, allows the user to avoid performing redundant Phase 2 computations.

Singularities - Selective grid point degrees of freedom are often singular in stiffness (as rotations about a vector normal to a plate) and may be constrained in Phase 1. However, if these grid points are later transformed to a new output coordinate system during a CØMBINE operation, the singularity may be re-introduced to the problem. NASTRAN substructuring transforms grid point degrees of freedom in groups of three translations and three rotations. Thus, if one or more translational and/or rotational degrees of freedom exist for a grid point and a general transformation (not 90°, 180°, or 270°) is applied, 3 translational and/or rotational degrees of freedom will exist for the resulting structure for that grid point. However, the stiffness matrix will be singular, and this must be considered in subsequent operations. For example, in future reduction operations some of these degrees of freedom must be kept in the boundary set so that the interior point stiffness matrix is non-singular. The extraneous singularities are finally removed at the SØLVE operation using SPCS or MPCS cards.

User Modes - The user may define a substructure in terms of modal data obtained from another source such as test data for example. To use this capability the user creates a Phase 1 job with an MREDUCE command as shown below.

```
SUBSTRUCTURE PHASE1
(SØF control cards)
NAME = name
MREDUCE name
  NAME = r-name
  USERMØDES = j
    .
    .
    .
```

Two options are allowed, j = 1 or 2. If j = 1, a structural model is defined as usual with bulk data cards. However, the modal data, i.e. the eigenvalue data and mode shape data, are defined by using direct input tables and matrices in the bulk data deck. Table LAMAR must be input using DTI cards using the format specified for the LAMA data block described in the Programmer's Manual. Only the modal mass and frequency (HZ) need be defined in LAMAR. The mode shapes must be input using DMI cards and the matrix name PHIS. The PHIS matrix must be the NASTRAN F-set size, i.e. the fixed degrees of freedom must be described with null rows.

If j = 2, the model is completely defined with matrix data. As is done for j = 1, a LAMAR table and PHIS matrix must be input. In addition, a matrix named QSM, which contains the modal reaction forces for degrees of freedom fixed in mode extraction, is input using DMI cards. Matrix QSM has one row for every degree of freedom (as does PHIS) and one column for every mode. Null row entries exist for degrees of freedom not fixed in mode extraction. Note that the number of modes must exceed the number of degrees of freedom for this option (see Section 18 of the Theoretical Manual). For the j = 2 option, the bulk data deck must include Grid cards to define the degrees of freedom represented by the rows of PHIS and QSM. In addition, a dummy element should be included in the data deck so that NASTRAN parameter values are properly set. The user may also input boundary mass and stiffness matrices. These data may be defined using CØNMi, CELASi, and GENEL cards, in which case dummy elements are not required, or may be input using DMI or DMIG cards. For the latter case, the user must insert the correct Executive Control Deck alters to equivalence the input mass and stiffness data to MGG and KGG respectively.

Boundary set definitions are required using BDYC, BDYS and BDYS1 cards for both user mode options. Note that all degrees of freedom defined for the j = 2 options must be specified as boundary degrees of freedom.

Old Modes and Old Boundaries - The ØLDMØDES and ØLDBØUND subcommands to the MREDUCE command allow the user to modify the new, modal coordinate substructure without performing all new calculations.

The ØLDMØDES subcommand requests that the mode shapes and frequencies computed in a previous MREDUCE be reused to define the modified structure. This is possible because all modes computed are saved on the SØF even if they are not currently used to describe the substructure. The user may request the previously used set of modes or a new subset of the previously calculated modes by his use of the NMAX or RANGE subcommands. Use of OLDMODES alone (without ØLDBØUND) implies that a new boundary set is to be defined for the reduced substructure. Use of this subcommand requires the additional subcommands BØUNDARY and NMAX or RANGE.

The ØLDBØUND subcommand requests that the boundary set definition not change for the modification to the substructure. For this case, a new set of modal data will be computed. Use of this subcommand requires the additional subcommands METHØD, NMAX or RANGE, and optionally FIXED, RNAME, and RGRID.

The use of both ØLDMØDES and ØLDBØUND implies only a change in the number of modes used from the previously computed set of modes. The use of both commands requires only a new NMAX or RANGE card as additional subcommands.

When using these subcommands the user must EDIT conflicting data from the SØF. Refer to the descriptions of MREDUCE and CREDUCE in Section 2.7 for details. Also note that both ØLDMØDES and ØLDBØUND are subcommands for MREDUCE, but only ØLDMØDES is allowed for CREDUCE. The equivalent operation of ØLDBØUND for CREDUCE requires complete redefinition of the reduced substructure.

Solution Items - It should be remembered that due to the data base protection features, at no time are there any SØF items destroyed by NASTRAN without a specific user command in the Substructure Control Deck. In addition, NASTRAN does not allow more than one substructure item (see Table 19) to exist for each substructure at any one time. As a result, some operations such as a repeated SØLVE might require the user to manually edit out previously generated solution data items or any recovered solution data items before the operation could be repeated. That is, SØLN

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and UVEC items (the load factor or eigenvalue data tables and displacement vectors respectively) created in an earlier SØLVE operation should be deleted if a new solution with new loads or frequency range is desired for the same substructure. These same items must also be edited out from each lower level substructure for which the new solution data will be recovered. SØLN and UVEC items are also created by MRECØVER and must be deleted prior to a SØLVE and RECØVER for the same structure.

By using the EQUIVALENCE operation to create an ident'cal structure, a new solution may be obtained for the same structure without deleting the older solution data items, as required in the example above.

Structural Design Considerations - Substructures which may change due to design iterations should be combined with other structures as late in the sequence of CØMBINE operations as possible. This will minimize the cost of creating a new solution structure. Also, if the design iteration changes are minor and their impact on other substructures in the model can be neglected, then RECØVER operations need be performed only from the lowest level of substructure affected by the changes. Frequently, these design changes can be evaluated using only the Phase 3 recovery calculations. Of course, care must be taken to maintain compatibility with the degree of freedom list defining the solution displacement vector. That is, the boundary grid points and connections should not be changed.

Table 16. Definitions of Substructure Terminology.

Basic Substructure	-	A structure formulated from finite elements in Phase 1.
Boundary Set	-	Set of degrees of freedom to be retained in a reduce operation.
Combine Operation	-	Merge two or more structures by connecting related degrees of freedom. The matrix elements for connected degrees of freedom are added to produce the combined structure matrices, and the substructure load vectors are processed and stored for subsequent combination at solution time.
Component Substructure	-	Any basic or pseudostructure comprising a part of an assembled substructure.
Connection Set	-	Set of grid points and their component degrees of freedom to be connected in adjoining structures.
Equivalence Operation	-	The creation of a secondary substructure equivalent to a primary substructure. Also creates image substructures back to the basic substructure level
Image Substructure	-	A substructure equivalent to an existing component substructure. May have different applied loads and/or solution vectors but has identical stiffness and mass matrices. Image substructures are automatically created as a result of an equivalence operation.
Phase (1, 2, or 3)	-	Basic steps required for multi-stage substructure processing with NASTRAN - creation, combination, reduction, solution and recovery, and detail data recovery.
Primary Substructure	-	Any basic substructure or any substructure resulting from a combine or reduce operation.
Pseudostructure	-	A combination of component substructures.
Reduce Operation	-	Structural matrix and load vector Guyan or modal reduction process to obtain smaller matrices.
Secondary Substructure	-	A substructure created from an equivalence operation.
SØF	-	Substructure Operating File. Contains all data necessary to define a structure at any stage, including solutions.
Solution Structure	-	The resulting substructure to be used in the solve operation.
Solve Operation	-	To obtain solutions using the present structural matrices and user-defined input data.

Table 17. Summary of Substructure Commands.

Phase and Mode Control	
# SUBSTRUCTURE	- Defines execution phase (1, 2, or 3)
NAME*	- Specifies Phase 1 substructure name
SAVEPLØT	- Requests plot data be saved in Phase 1
ØPTIØNS	- Defines matrix options (K, B, K4, M, P, or PA)
RUN	- Limits mode of execution (DRY, GØ, DRYGØ, STEP)
# ENDSUBS	- Terminates Substructure Control Deck

SØF Controls	
# SØF	- Assigns physical file for storage of the SØF
PASSWØRD*	- Protects and ensures access to correct file
SØFØUT or SØFIN	- Copies SØF data to or from an external file
PØSITIØN	- Specifies initial position of input file
NAMES	- Specifies substructure name used for input
ITEMS	- Specifies data items to be copied in or out
SØFPRINT	- Prints selected items from the SØF
DUMP	- Dumps entire SØF to a backup file
RESTØRE	- Restores entire SØF from a previous DUMP operation
CHECK	- Checks contents of external file created by SØFØUT
DELETE	- Deletes out selected groups of items from the SØF
EDIT	- Edits out selected groups of items from the SØF
DESTRØY	- Destroys <u>all</u> data for a named substructure and <u>all</u> the substructures of which it is a component

Manditory Control Cards

* Required Subcommand

Table 17. Summary of Substructure Commands (continued).

Substructure Operations	
CØMBINE	- Combines sets of substructures
NAME*	- Names the resulting substructure
TØLERANCE*	- Limits distance between automatically connected grids
CØNNECT	- Defines sets for manually connected grids and releases
ØUTPUT	- Specifies optional output results
CØMPØNENT	- Identifies component substructure for special processing
TRANSFØRM	- Defines transformations for named component substructures
SYMTRANSFØRM	- Sepcifies symmetry transformation
SEARCH	- Limits search for automatic connects
EQUIV	- Creates a new equivalent substructure
PREFIX*	- Prefix to rename equivalenced lower level substructures
REDUCE	- Reduces substructure matrices
NAME*	- Names the resulting substructure
BØUNDARY*	- Defines set of retained degrees of freedom
RSAVE	- Indicates the decomposition product of the interior point stiffness matrix is to be saved on the SØF
ØUTPUT	- Specifies optional output requests
MREDUCE	- Reduces substructure matrices using a normal modes transformation
NAME*	- Names the resulting substructure
BØUNDARY*	- Defines set of retained degrees of freedom
FIXED	- Defines set of constrained degrees of freedom for modes calculation
RNAME	- Specifies basic substructure to define reference point for inertia relief shapes
RGRID	- Specifies grid point in the basic substructure to define reference point for inertia relief shapes. Defaults to origin of basic substructure coordinate system
METHØD	- Identifies EIGR Bulk Data card
RANGE	- Identifies frequency range for retained modal coordinates
NMAX	- Identifies number of lowest frequency modes for retained modal coordinates
ØLDMØDES	- Flag to identify rerunning problem with previously computed modal data
ØLDBØUND	- Flag to identify rerunning problem with previously defined boundary set

* Required Subcommand

Table 17. Summary of Substructure Commands (continued).

Substructure Operations	
USERMØDES	- Flag to indicate modal data have been input on bulk data
ØUTPUT	- Specifies optional output requests
RSAVE	- Indicates the decomposition product of the interior point stiffness matrix is to be stored on the SØF.
CREDUCE	- Reduces substructure matrices using a complex modes transformation
NAME*	- Names the resulting substructure
BØUNDARY*	- Defines set of retained degrees of freedom
FIXED	- Defines set of constrained degrees of freedom for modes calculation
METHØD	- Identifies EIGC Bulk Data card
RANGE	- Identifies frequency range of imaginary part of the root for retained modal coordinates
NMAX	- Identifies number of lowest frequency modes for retained modal coordinates
ØLDMØDES	- Flag to identify rerunning problem with previously computed modal data
GPARAM	- Specifies structural damping parameter
ØUTPUT	- Specifies optional output requests
RSAVE	- Indicates the decomposition product of the interior point stiffness matrix is to be stored on the SØF
MRECØVER	- Recovers mode shape data from an MREDUCE or CREDUCE operation
SAVE	- Stores modal data on SØF
PRINT	- Stores modal data and prints data requested
SØLVE	- Initiates substructure solution (statics, normal modes, frequency response, or transient response)
RECØVER	- Recovers Phase 2 solution data
SAVE	- Stores solution data on SØF
PRINT	- Stores solution and prints data requested
BRECØVER	- Basic substructure data recovery, Phase 3
PLØT	- Initiates substructure undeformed plots

* Required Subcommand

Table 18. Substructure Bulk Data Card Summary.

Bulk Data Used By Substructure Commands REDUCE, MREDUCE, and CREDUCE
BDYC - Combination of substructure boundary sets of retained degreed of freedom or fixed degrees of freedom for modes calculation
BDYS - Boundary set definition
BDYS1 - Alternate boundary set definition
Bulk Data Used By Substructure Command CØMBINE
CØNCT - Specifies grid points and degrees of freedom for manually specified connectivities - will be overridden by RELES data
CØNCT1 - Alternate specification of connectivities
RELES - Specifies grid point degrees of freedom to be disconnected - overrides CØNCT and automatic connectivities
GTRAN - Redefines the output coordinate system grid point displacement sets
TRANS - Specifies coordinate systems for substructure and grid point transformations
Bulk Data Used by Substructure Command SØLVE
LØADC - Defines loading conditions for static analysis
MPCS - Specifies mulitpoint constraints
SPCS - Specifies single-point constraints
SPCS1 - Alternate specification of single-point constraints
SPCSD - Specifies enforced displacements for single-point constraints
DAREAS - Specifies dynamic loadings
DELAYS - Specifies time delays for dynamic loads
DPHASES- Specifies phase lead terms for dynamic loads
TICS - Specifies transient initial conditions

Table 19. Substructure Item Descriptions.

EQSS	External grid point and internal point equivalence data
BGSS	Basic grid point coordinates
CSTM	Local coordinate system transformation matrices
LØDS	Load set identification numbers
LØAP	Load set identification numbers for appended load vectors
PLTS	Plot sets and other data required for Phase 2 plotting
KMTX	Stiffness matrix
LMTX	Decomposition product of REDUCE operation
MMTX	Mass matrix
PAPP	Appended load vectors
PVEC	Load vectors
PØAP	Appended load vectors on omitted points
PØVE	Load vectors on points omitted during matrix reduction
UPRT	Partitioning vector used in matrix reduction
HØRG	H or G transformation matrix
UVEC	Displacement vectors or eigenvectors
QVEC	Reaction force vectors
SØLN	Load factor data or eigenvalues used in a solution
LAMS	Eigenvalue data from modal reduce operation
PHIS	Eigenvector matrix
GIMS	G transformation matrix for interior points from a modal reduction
K4MX	Structural damping matrix
BMTX	Viscous damping matrix
PHIL	Left side eigenvector matrix from unsymmetric CREDUCE operation
HLFT	Left side H transformation matrix from unsymmetric CREDUCE operation

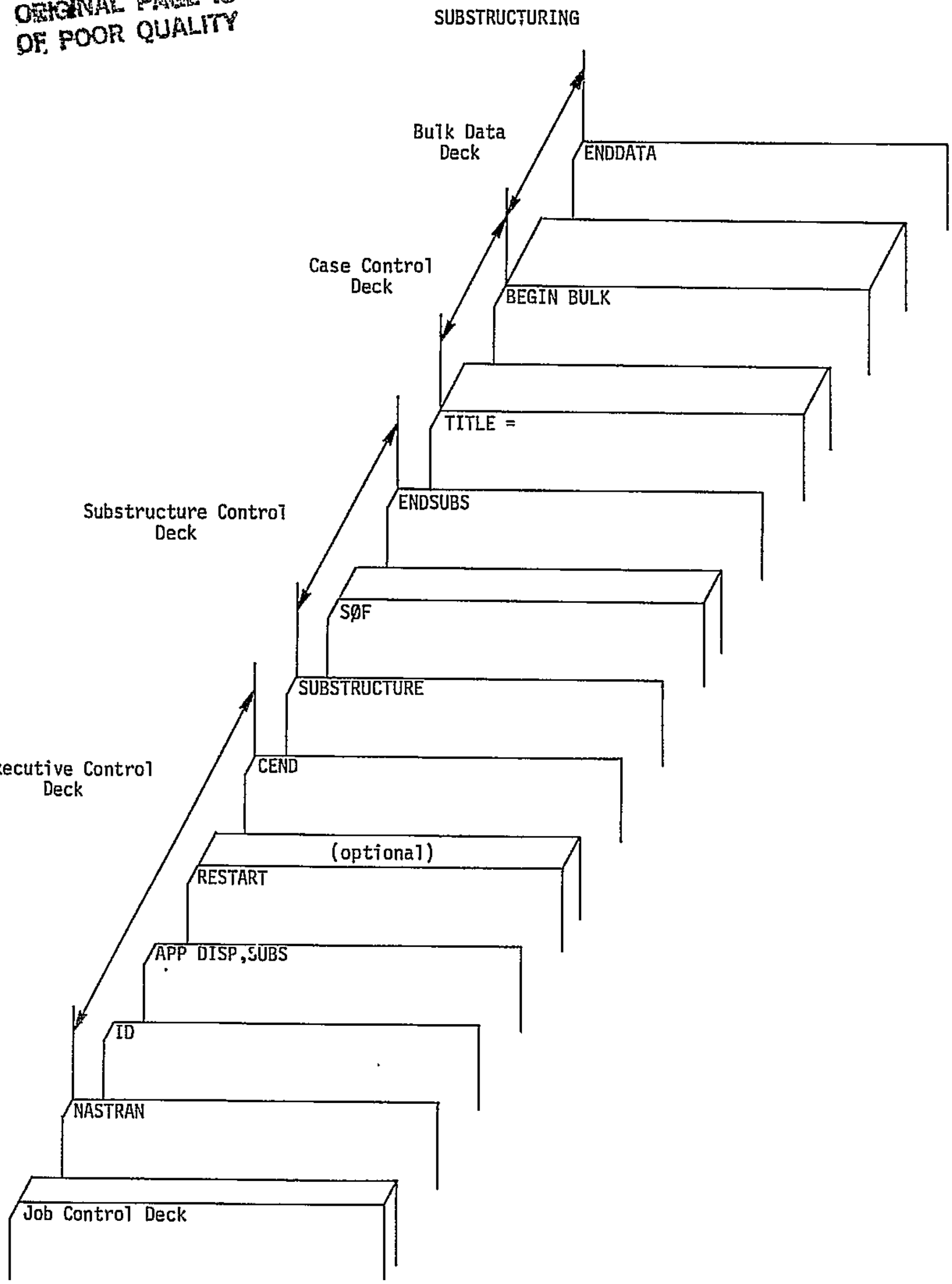

Figure 2. Substructuring input data deck.

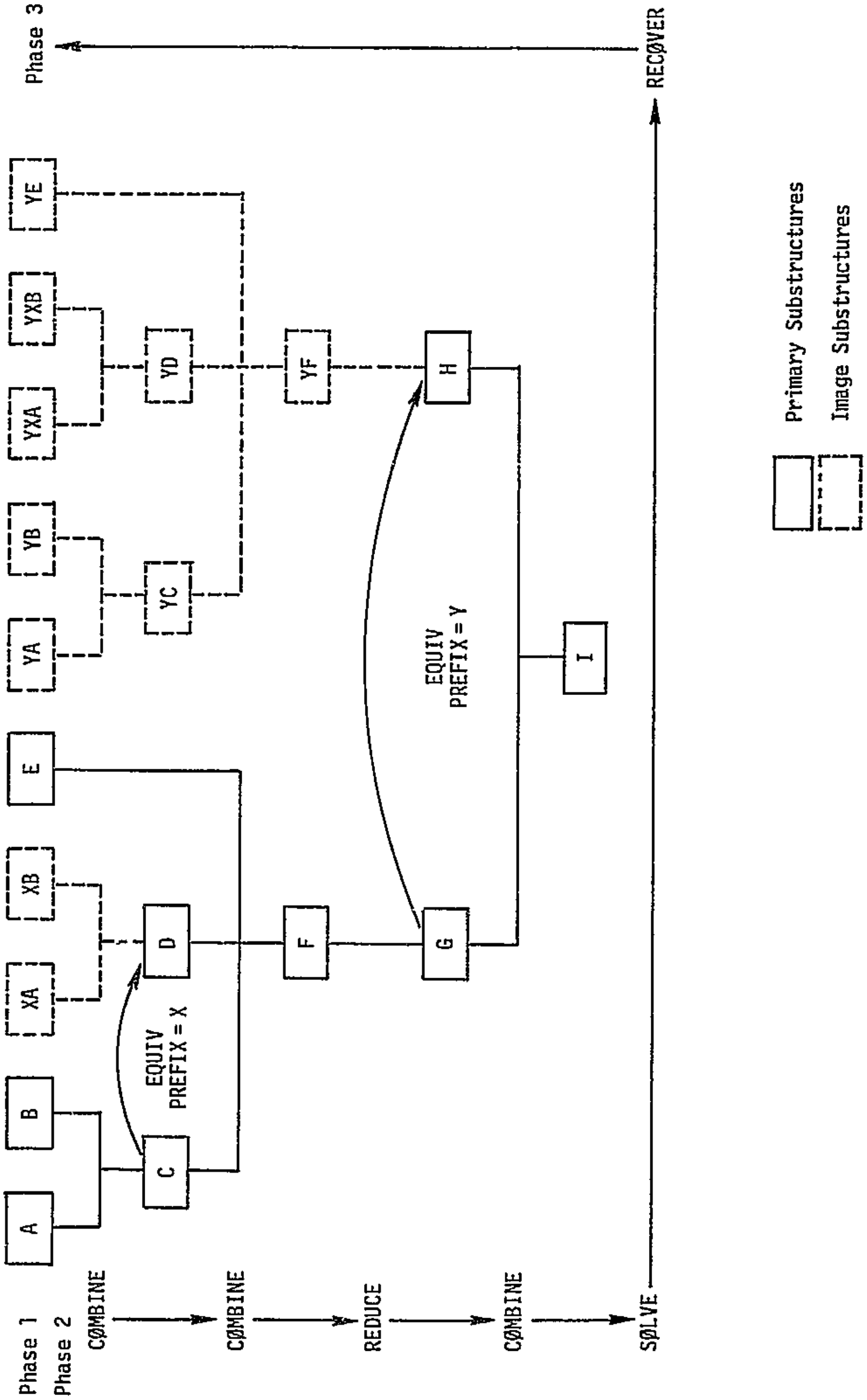

Figure 3. Example of multi-stage substructuring.

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S U B S T R U C T U R E   Ø P E R A T I N G   F I L E   T A B L E   Ø F   C Ø N T E N T S

SUBSTRUCTURE NØ.	NAME	TYPE	SS	PS	LL	CS	HL	EQSS	BGSS	CSTM	LØDS	PLTS	KMTX	MMTX	PVEC	PØVE	UPRT	HØRG	UVEC	QVEC	SØLN	PAPP	PØAP	LØAP	LMTX	GIMS	PHIS	LAMS	K4MX	BMTX	PHIL	HLFT
1	VANE	B	5	0	0	3	6	2	2		2		2	2	2			2	2													
2	RING	B	0	0	0	1	6	2	2		2		2	2	2			2	2													
3	VANER	B	0	1	0	4	6	2	2		2		2	2	2			2														
4	VANEB	B	3	1	0	5	6	2	2		2		2	2	2			2														
5	VANEL	B	4	1	0	2	6	2	2		2		2	2	2			2														
6	WINDMILL	C	0	0	2	0	0	2	2		2	2	2	2	2				2	2												

SIZE ØF ITEM IS GIVEN IN PØWERS ØF TEN   (0 INDICATES DATA IS STØRED IN PRIMARY)

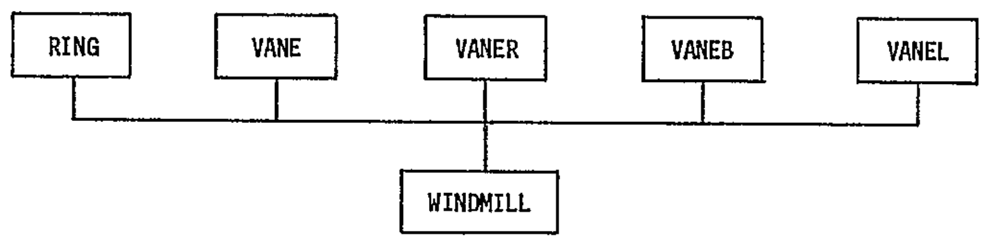

Figure 4. Sample of Substructure Operating File Table of Contents.

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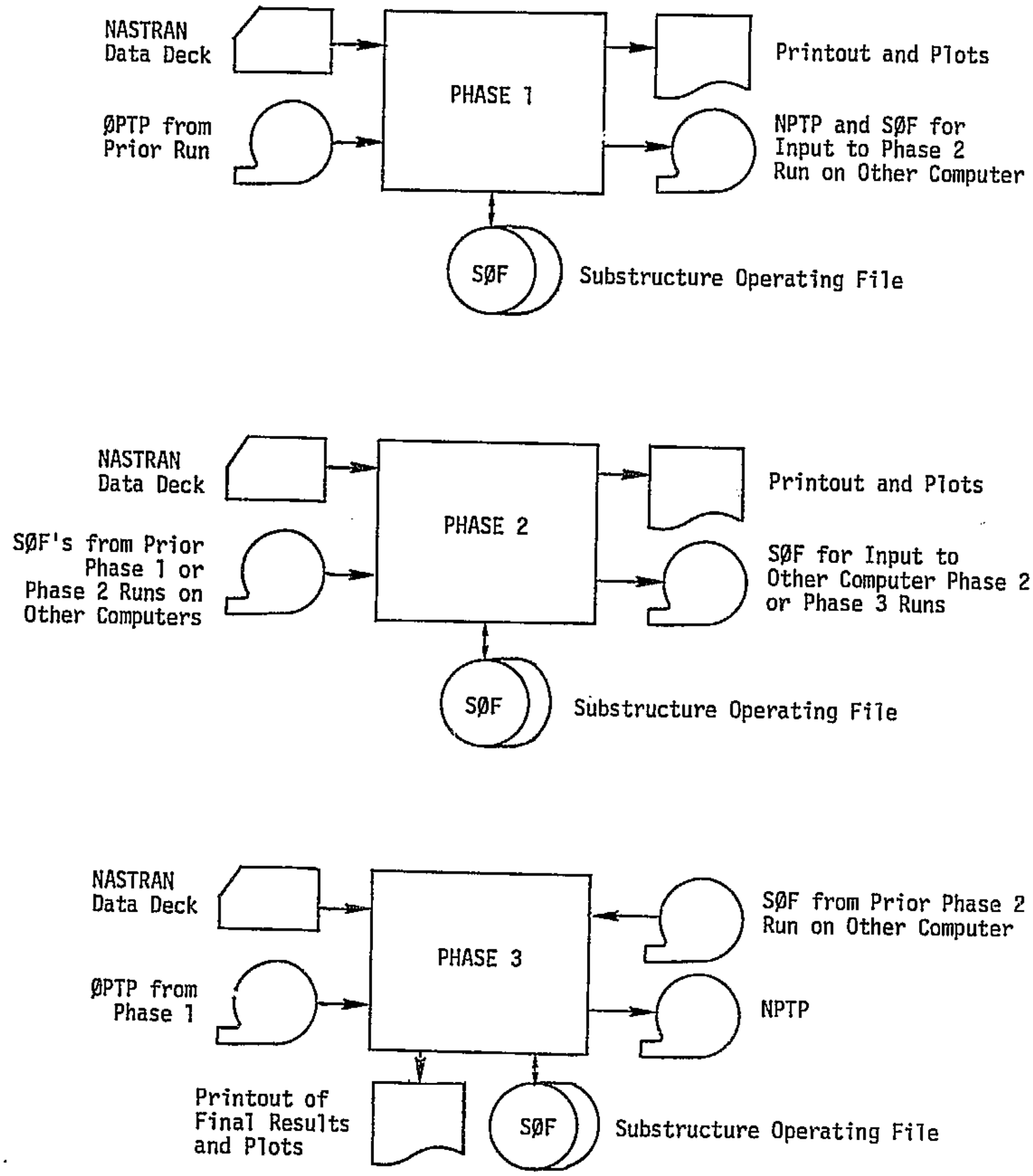


Note: If all processing is performed on the same computer, SØF tape output is not required. All communication may be carried out using the same SØF disk/drum throughout.

Figure 5. Data file organization for NASTRAN multi-stage substructuring.

1.11 AEROELASTIC MODELING

1.11.1 Introduction

The NASTRAN aeroelastic capability is intended for the study of stability and response of aeroelastic systems. It is compatible with the general structural capability, but it is not designed for use with other special capabilities such as conical shell elements, hydroelastic option, and acoustic cavity analysis. The structural part of the problem will be modeled as described in other sections of this manual. This section deals with the aerodynamic data and the connection between structural and aerodynamic elements.

Section 1.11.2 deals with the aerodynamic data. The selection of a good aerodynamic model will depend upon a knowledge of the theory (see Section 17.5 of the Theoretical Manual). Several choices of aerodynamic theory are available. All assume small amplitude sinusoidal motions. Transient aerodynamic forces are obtained by Fourier methods.

Section 1.11.3 deals with the interconnection between aerodynamic and structural degrees of freedom. The interpolation methods include both linear and surface splines. These methods are superior to high order polynomials since they tend to give smooth interpolation. They are based upon the theory of uniform beams and plates of infinite extent (see Section 17.3 of the Theoretical Manual).

Section 1.11.4 describes modal flutter analysis by the three available methods.

Section 1.11.5 gives instructions for modal aerodynamic response analysis. This includes frequency response, transient response and random analysis. The excitation may consist of applied forces or gusts (Doublet-Lattice theory only).

1.11.2 Aerodynamic Modeling

Aerodynamic elements define the interaction between the structure and an airflow. Since the elements usually occur in regular arrays, the connection cards are designed to specify arrays. The grid points associated with the elements in an array are generated within the program. Spline methods are used to interpolate for aerodynamic grid point deflection in terms of structural points.

For every aerodynamic problem, basic parameters are specified on the AERØ bulk data card. A rectangular aerodynamic coordinate system must be identified. The flow is in the positive x-direction in this system. The use of symmetry (or antisymmetry) is recommended to analyze symmetric structures, to simulate ground effects, or to simulate wind tunnel walls. Any consistent set of units can be used for the dimensional quantities.

The types of elements available are shown in Table 1. Every CAERØi element must reference a PAERØi data card, which is used for additional parameters. Lists of real numbers are sometimes required, which are given on AEFACT lists. These lists may include division points (for unequal box sizes) and parameter values.

1.11.2.1 Doublet-Lattice Panels

The lifting surfaces are idealized as planes parallel to the flow. The configuration is divided into plane panels (macro-elements), each of constant dihedral. These panels are further subdivided into "boxes" (see Figure 1), which are trapezoids with sides parallel to the airflow direction. If an airfoil lies in (or nearly in) the wake of another, then the spanwise divisions should lie along the same streamline. The boxes should be arranged so that any fold or hinge lines lie along the box boundaries. The aspect ratio of the boxes should be roughly unity or less. The chord length of the boxes should be less than 0.08 times the velocity divided by the greatest frequency of interest, but no less than four boxes per chord should be used. Boxes should be concentrated near wing edges and hinge lines or any other place where downwash is discontinuous. A further discussion of the choice of models is found in Reference 1. Aerodynamic panels are assigned to groups. All panels within a group have aerodynamic interaction. The purpose of the groups is to reduce the time to compute aerodynamic matrices when it is known that aerodynamic interference is unimportant, or to allow the analyst to investigate the effects of aerodynamic interference.

Each panel is described by a bulk data CAERØ1 card. A property card PAERØ1 may be used to identify associated interference bodies. It is recommended that a body be identified if the panel is less than one body diameter from the body. The box divisions along the span are determined either by specifying the number of equal boxes (NSPAN) or the identity (LSPAN) of an AEFACT data card which gives a list of division points in terms of a fraction of the span. A similar arrangement is used in the chord direction. The locations of the two leading edge points are specified in any coordinate system (CP) defined by the user (including BASIC). The lengths of the sides are specified by the user, and they are in the airstream direction, assuring that the panel is parallel to the flow. Every panel must be assigned to some group (IGID). If all panels interact, then select IGID = 1 for all panels.

There will be many degrees of freedom associated with each aerodynamic panel. There is an aerodynamic grid point associated with each box within a given panel. These points are located at the center of each box and are automatically numbered and sequenced by the program. The lowest aerodynamic grid point number for a given panel is assigned the same number specified for the panel designation. The grid point numbers increase in increments of 1 (see CAERØ1 data card figure) over all boxes in the panel. The user must be aware of these internally generated grid points and ensure that their numbers are distinct from structural grid points. These aerodynamic points are used for output including displacements, plotting, matrix prints, etc. The local displacement coordinate system has component T1 in the flow direction and component T3 in the direction normal to the panel (the element coordinate system of CAERØ1).

1.11.2.2 Slender and Interference Bodies

The bodies are idealized as either "slender" or "interference" elements. The major purpose of the slender body elements is to account for the forces arising from the motion of the body, while the "interference" elements account for the effects of the body upon the panels and other bodies. Bodies are further classified as to the type of motion allowed. In the aerodynamic coordinate system, y and z are perpendicular to the flow. In general, bodies may move in both the y- and z-directions. Frequently, a body (e.g., a fuselage) lies on a plane of symmetry and only z (or y) motion is allowed. Thus, any model may contain z-bodies, zy-bodies, and y-bodies. One or two planes of symmetry or antisymmetry may be specified. Figure 2 shows an idealization with bodies and panels. This example case is the one used to illustrate the Doublet-Lattice program in Ref. 2. It has a body (on the midplane), a wing, pylon and nacelle.

The location of a body is specified on a CAERØ2 data card. The location of the nose and the length in the flow direction are given. The slender body elements and interference elements are distinct quantities and must be specified separately. At least two slender body elements are required for every aerodynamic body, while interference elements are optional. The geometry is given in terms of the element division points, and the width and height of the assumed elliptical cross section. The locations of the division points may be given in dimensionless units or, if the lengths are equal, only the number of elements need be specified. The semi-width of the two types of elements may be specified separately and are given in units of length. Usually the slender body semi-width is taken as zero at the nose and is a function of x, while the interference body semi-width is taken to be constant. The height-to-width ratio must be constant for each body.

These body elements are primarily intended for use with Doublet-Lattice panels. The interference elements are only intended for use with panels, while slender body elements can stand alone. Grid points will be generated only for the slender body elements. The first grid point will be assigned the ID of the body and other grid points will be incremented by one. The user must ensure that the IDs of these generated grid points are distinct from all other grid points in the model.

There are some rules about bodies which have been imposed. All z-only bodies must have lower ID numbers than zy-bodies, which in turn must have lower ID numbers than y-only bodies. The total number of interference bodies associated with a panel is limited to six. The user should be cautious about the use of associated interference bodies since they tend to increase computing time significantly.

1.11.2.3 Mach Box Theory

Mach box aerodynamics may be used to compute unsteady supersonic aerodynamic forces for a flat, isolated wing at supersonic speeds. The surface (see Figure 3) may have a leading and/or trailing edge crank (change of angle). There may be one or two adjacent (to each other) trailing edge control surfaces. The "inboard" edge (side 1-2 on the connection card) must be a plane of aerodynamic symmetry or antisymmetry.

The geometry of the planform is specified on the CAERØ3 data card. Two leading edge corners (points 1 and 4 of Figure 3) are located by the user, using any NASTRAN coordinate system. These, along with the flow direction, define the plane of the wing. Up to ten additional points are permitted to specify cranks and controls; these are dimensional quantities using a coordinate system in the plane of the wing and with origin at point 1.

The aerodynamic grid points for interconnection are in the plane of the element. The user must specify a list of x,y pairs for the wing. These are located using the coordinate system shown in Figure 3. There must be at least three points. Additional lists of at least three points are needed for each control surface which is used. The T3 component of these aerodynamic grid points is normal to the plane of the element. Interpolation for deflections and slopes at Mach box locations is done by surface spline routines within the program. Thus the control point locations can be held fixed, even when the Macn number is changed. These aerodynamic grid points will be numbered, starting with the element ID, and must be distinct from all other grid points.

The following restrictions must be satisfied:

1. The leading edge and hinge line sweepback angles must be greater than or equal to zero.

2. All control surface sides must be parallel to the flow, or else the aft point of the control surface side must be inboard of the forward point.

3. If a leading edge crank is not present, then x_5,y_5 do not have to be input.

4. If a trailing edge crank is not present, then x_6,y_6 do not have to be input.

5. A trailing edge crank cannot be located on a control surface. It must be located inboard, outboard, or exactly at the junction of the two control surfaces.

6. Points 8, 10, and 12 are used with points 7, 9, and 11 respectively to define the control surface edges. They must be distinct from points 7, 9, and 11, but they do not have to lie on the wing trailing edge. The program will calculate new points 8, 10, and 12 for the wing trailing edge. However, points 8, 10, or 12 must be located on the trailing edge if the trailing edge crank is located at the left corner of control surface one (1) or the right corner of control surface two (2) or between the two control surfaces. For example, set $x_8 = x_6$ and $y_8 = y_6$ if the crank is at the left corner of control surface one.

7. When only one control surface is present, it must be control surface one (1).

8. If control surface two (2) is not present, then x_{11},y_{11} and x_{12},y_{12} are not required as input.

9. If no control surfaces are present, then x_i,y_i (i = 7 through 12) are not required as input.

10. No aerodynamic balance for the control surfaces has been included in the Mach Box Theory.

11. The number of chordwise boxes used as input (NBØX) to the program should be carefully selected. Note that NBØX is the number of chordwise divisions from the most forward point to the most aft point on the lifting surface, as shown in Figure 4. If the maximum number of allowable boxes (200 on the main surface, 125 on each control surface) is exceeded, the program will reduce the number of chordwise boxes one at a time until the number of boxes is under the allowable limit. Expenditure of excessive computer time may occur during this process.

12. The edge 1-2 will be taken as a plane of symmetry unless SYMXZ=-1 (see AERØ data card).

1.11.2.4 Strip Theory

Modified strip theory can be used for unsteady aerodynamic forces on a high aspect ratio lifting surface. Each strip may have two or three degrees of freedom. Plunge and pitch are always used, and an aerodynamically balanced control surfaced is optional. If a control surface is present, either a sealed or an open gap may be used.

The planform (which may have several strips in one macro-element) is specified on a CAERØ4 bulk data card. A sample planform is shown in Figure 5. The user supplies the two leading edge corner locations and the edge chords as dimensional quantities. Edge chords are assumed parallel to the flow. All additional geometry (box divisions, hinge locations, etc.) are given in dimensionless units. Several CAERØ4 cards may be used if there are several surfaces or cranks.

A grid point is assigned to each strip, and will be assigned an ID starting with the macro-element ID and incrementing by one for each strip. The plunge (T3) and pitch (R2) degrees of freedom have the conventional definition. When a control surface is present, the R3 degree of freedom has a nonstandard definition, which is the <u>relative</u> control rotation. When interconnecting with the structure, the ordinary (surface or linear) splines can be used for T3 and R2, but a special method (see SPLINE3 data card) is used for the relative control rotation.

The parameters such as lift curve slope or lag function may be varied to account for tip effects (three-dimensional flow) and Mach number by AEFACT data card selection from PAERØ4. The AEFACT data card format used by strip theory is shown in the remarks on the PAERØ4 data card. The user may request a Prandtl-Glauert (compressibility and sweep) correction to the value of the

curve slope. The lag function depends upon the local (i.e., using the chord of the strip) reduced frequency. For incompressible flow, it is the Theordorsen function C(k). An approximate form for this function is given by

$$C(k) = \sum_{n=0}^{N} \frac{b_n}{1-i\ \beta_n/k} \quad , \tag{1}$$

where $\beta_0 = 0$, may be selected for computing lags. The choice of parameters b_n and β_n is left to the user so that he may select values suitable for his requirement. Reference 3 gives values for various Mach numbers and aspect ratios.

1.11.2.5 Piston Theory

Piston theory in NASTRAN is a form of strip theory. The aerodynamic forces are computed from third order piston theory, which is valid for high Mach numbers $m >> 1$, or sufficiently high reduced frequency $m^2k^2 >> 1$. Although the latter condition may be met in subsonic flow, the primary application of piston theory is in supersonic flow.

The coefficients of the point pressure function (relating local pressure to local downwash) may be modified to agree with the Van Dyke theory and to account for sweepback effects. The resulting strip parameters will depend upon the wing thickness distribution and spanwise variation of initial angle of attack, which must be supplied by the user. The point pressure function is given by $Cp = -(4/m)[\overline{C}_1 + 2\overline{C}_2\ mg_x + 3C_3m^2\ (g_x^2 + \alpha_0^2)]\ v$, where

Coefficient	Van Dyke theory with Sweep	Piston Theory
$\overline{C}_1$	$m/(m^2 - s^2)^{1/2}$	1
$\overline{C}_2$	$[m^4(\gamma+1) - 4s^2\ (m^2 - s^2)]/4(m^2-s^2)^2$	$(\gamma+1)/4$
C_3	$(\gamma+1)/12$	$(\gamma+1)/12$

and where

- Cp local pressure coefficient (pressure rise divided by dynamic pressure)
- g_x derivative of airfoil semi-thickness in the flow direction
- m Mach number
- s secΛ, secant of sweepback angle

v unsteady dimensionless downwash

α_0 initial angle of attack

γ ratio of specific heats = 1.4

Geometry specification and interconnection points follow the same rules as for strip theory (see Section 1.11.2.4). The additional information about angle of attack and thickness is given on AEFACT data cards which are referenced by the CAERØ5 and PAERØ5 data cards. The AEFACT data card format used by piston theory is shown in the remarks on the PAERØ5 data card. If thickness integrals are input on AEFACT data cards, see the thickness integral definitions on the CAERØ5 data card.

1.11.3 The Interconnection Between Structure and Aerodynamic Models

The interpolation between the structural and aerodynamic degrees of freedom is based upon the theory of splines (Figure 6). High aspect ratio wings, bodies, or other beamlike structures should use linear splines. Low aspect ratio wings, where the structural grid points are distributed over an area, should use surface splines. Several splines can be used to interpolate to the boxes on a panel or elements on a body; however, each point can refer to only one spline. Any box or body element not referenced by a spline will be "fixed" and have no motion. For any point, especially a control surface degree of freedom, a linear relationship (like an MPC) may be specified.

For all types of splines, the user must specify the structural degrees of freedom and the aerodynamic points involved. The structural points, called the g-set, can be specified by a list or by specifying a volume in space and determining all the grid points in the volume. The degrees of freedom retained at the grid points include only the normal displacements for surface splines. For linear splines, the normal displacement is always used and, by user option, torsional rotations or slopes may be included. The global transformation at structural points is automatically applied for surface and linear splines.

The SPLINE1 data card defines a surface spline. This can interpolate for any "rectangular" subarray of boxes on a panel. For example, one spline can be used for the inboard end of a panel and another for the outboard end. The interpolated grid points (k-set) are specified by naming the lowest and highest aerodynamic grid point numbers in the area to be splined. The two methods for specifying the grid points use SET1 and SET2 data cards. A parameter DZ is used to allow some

smoothing of the spline fit. If DZ = 0 (the usual value), the spline will pass through all deflected grid points. If DZ > 0, then the spline (a plate) is attached to the grid deflections via springs, which produce a smoother interpolation that does not necessarily pass exactly through any of the points. The flexibility of the springs is proportional to DZ.

The SPLINE2 data card defines a linear spline. As can be seen from Figure 6, this is really a generalization of a simple spline to allow for interpolation over an area. It is similar to the method often used by aeronautical engineers who assume that an airfoil chord is rigid. The portion of a panel to be interpolated and the set of structural points are determined in the same manner as with SPLINE1. A NASTRAN coordinate system must be supplied to determine the axis of the spline. Since the spline has torsion as well as bending flexibility, the user may specify the ratio of flexibilities; the default value for this ratio is 1.0. The attachment flexibilities, D_z, $D_{\theta x}$, and $D_{\theta y}$, allow for smoothing, but usually all values are taken to be zero. An exception would occur if the structural model does not have slopes defined, in which case the flexibility DTHX must be infinite; the convention DTHX = -1.0 is used in this case. When used with bodies, there is no torsion and the spline axis is along the body.

There are certain cases with splines where attachment flexibility is either required or should not be used. The following special cases should be noted.

1. Two or more grid points, when projected onto the plane of the element (or the axis of a body) may have the same location. To avoid a singular interpolation matrix, a positive attachment flexibility must be used.

2. With linear splines, three deflections with the same spline y-coordinate would overdetermine the interpolated deflections since the perpendicular arms are rigid. A positive DZ is needed to make the interpolation matrix nonsingular.

3. With linear splines, two slopes (or twists) at the same y-coordinate would lead to a singular interpolation matrix. Use DTHX > 0 (or DTHY > 0) to allow interpolation.

4. For some modeling techniques, i.e., those which use only displacement degrees of freedom, the rotations of the structural model are constrained to zero to avoid matrix singularities. If a linear spline is used, the rotational constraints should not be enforced to these zero values. When used for panels, negative values of DTHX will disconnect the slope, and negative values of DTHY will disconnect the twist. For bodies, DTHY constrains the slopes since there is no twist degree of freedom for body interpolation. For a linear spline, if all of the structural points lie on a straight line, the use of infinite (negative DTHX or DTHY) rotational flexibility results in a kinematically unstable idealization.

For linear splines used with wings, the parameter DTØR should be selected as a representative value of EI/GJ.

1.11.4 Modal Flutter Analysis

The purpose of modal flutter analysis is to study the stability of an aeroelastic system with a minimum number of degrees of freedom. A prerequisite to modal flutter analysis is the calculation of an aerodynamic matrix with a transformation to modal coordinates. This operation is often very costly and care should be taken to avoid unnecessary computations. One method is to compute the modal aerodynamic matrix at a few Mach numbers and reduced frequencies and interpolate to others. Matrix interpolation is an automatic feature of the flutter rigid format. The MKAERØ1 and MKAERØ2 data cards allow the selection of parameters for the aerodynamic matrix calculation on which the interpolation is based.

The method of flutter analysis is specified on the FLUTTER bulk data card. The FLUTTER card is selected in case control by an FMETHØD card. Three methods of flutter analysis are available; K, KE and PK. These are shown in Table 2.

The K-method allows looping through three sets of parameters: density ratio (ρ/ρ_{ref}; ρ_{ref} is given on an AERØ data card); Mach number m; and reduced frequency k. For example, if the user specifies two values of each, there will be eight loops in the following order.

LØØP (CURVE)	DENS	MACH	REFREQ
1	1	1	1
2	2	1	1
3	1	1	2
4	2	1	2
5	1	2	1
6	2	2	1
7	1	2	2
8	2	2	2

Values for the parameters are listed on FLFACT bulk data cards. Usually, one or two of the parameters will have only a single value. Caution: do not set up a large number of loops; it may take an excessive time to execute.

A parameter VREF may be used to scale the output velocity. This can be used to convert from consistent units (e.g., in/sec) to any units the user may desire (e.g., knots), determined from $V_{out} = V/V_{REF}$. Another use of this parameter is to compute the flutter index, by choosing $V_{REF} = b\omega_\theta \sqrt{\mu}$.

If physical output (grid point deflections or element forces, plots, etc.) is desired rather than modal amplitudes, this data recovery can be made upon a user selected subset of the cases. The selection is based upon the velocity; the method is discussed in Section 3.20.4.

The KE-method is similar to the K method. By restricting the option, the KE-method is a more efficient K-method. The two major restrictions are that no damping (B) matrix is allowed and no eigenvector recovery is made. This means that the KE-method is not suitable for a control system, but it is a good method for producing a large number of points for the classical V-g curve. The KE-method also sorts the data for plotting. A plot request for one curve gives all of the reduced frequencies for a mode while a similar request in the K-method gives all of the modes at one k value.

The PK-method treats the aerodynamic matrices as frequency dependent springs and dampers. A frequency is estimated and the eigenvalues are found. From an eigenvalue, a new frequency is found. The convergence to a consistent root is very rapid. The major advantage of the method is that the damping values obtained at subcritical flutter conditions appear to be more representative of the physical damping. Another advantage occurs when the stability at a specified velocity is required since many fewer eigenvalue analyses are needed to find the behavior at one velocity.

The input data for the PK-method also allows looping, as in the K method. The inner loop of the user data is velocity, with Mach number and density on outer loops. Thus, the effects of varying any or all of the three parameters on one run is possible.

Subsets of flutter analysis for checking data are listed under the description of the SØL card in Section 2.2.3.

1.11.5 Modal Aeroelastic Response Analysis

The purpose of the modal aeroelastic response analysis is to study the behavior of an aeroelastic system resulting from applied loads and gusts. One rigid format can solve frequency response, random response, and transient response problems. The capability includes control systems (using NASTRAN Extra Points and Transfer Functions), multiple loading conditions (with SUBCASES), and rigid body modes.

The input data deck is the same as for the flutter analysis, except for load requests and output selection. The point loads are applied with standard RLØAD (frequency response) or TLØAD (transient response) data cards. For gust fields, which are only implemented for the Doublet-Lattice/Body Aerodynamic theory, the vertical stationary gust velocity can be specified with either RLØAD or TLØAD cards. In this manner, the response to either random or time-dependent gusts may be obtained.

For random response analysis, the power spectral density of the load must be supplied. For gusts, either the Von Karman or the Dryden formula can be selected. The output power spectral density is requested by the XYØUT Case Control cards. The r.m.s. value and N_0, the expected frequency, are automatically printed when PSDF information is requested.

The user must supply the basic flight conditions. The velocity is specified by the AERØ data card, while Mach number and dynamic pressure (q) are supplied on PARAM bulk data cards.

The damping must be modal damping. Ordinarily, a modal viscous damping is assumed, as in the NASTRAN modal dynamic rigid format. A parameter KDAMP=-1 can be used to substitute modal structural damping, the modal stiffness is multiplied by $[1+ig(\omega)]$.

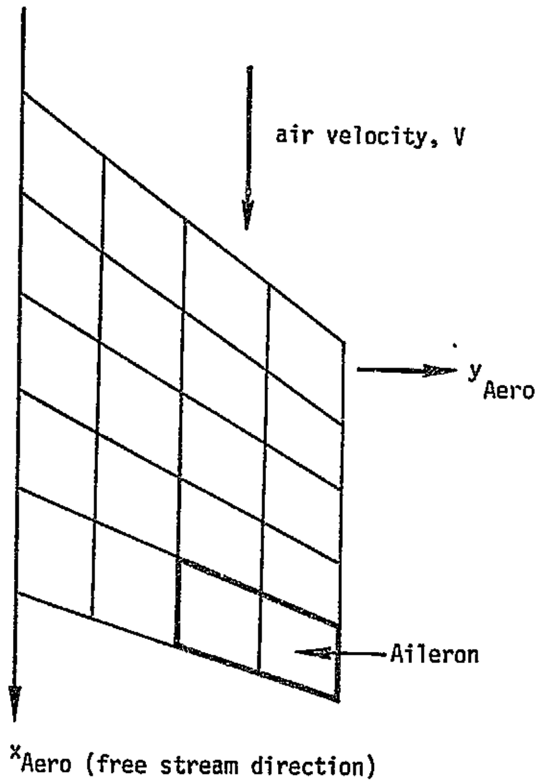
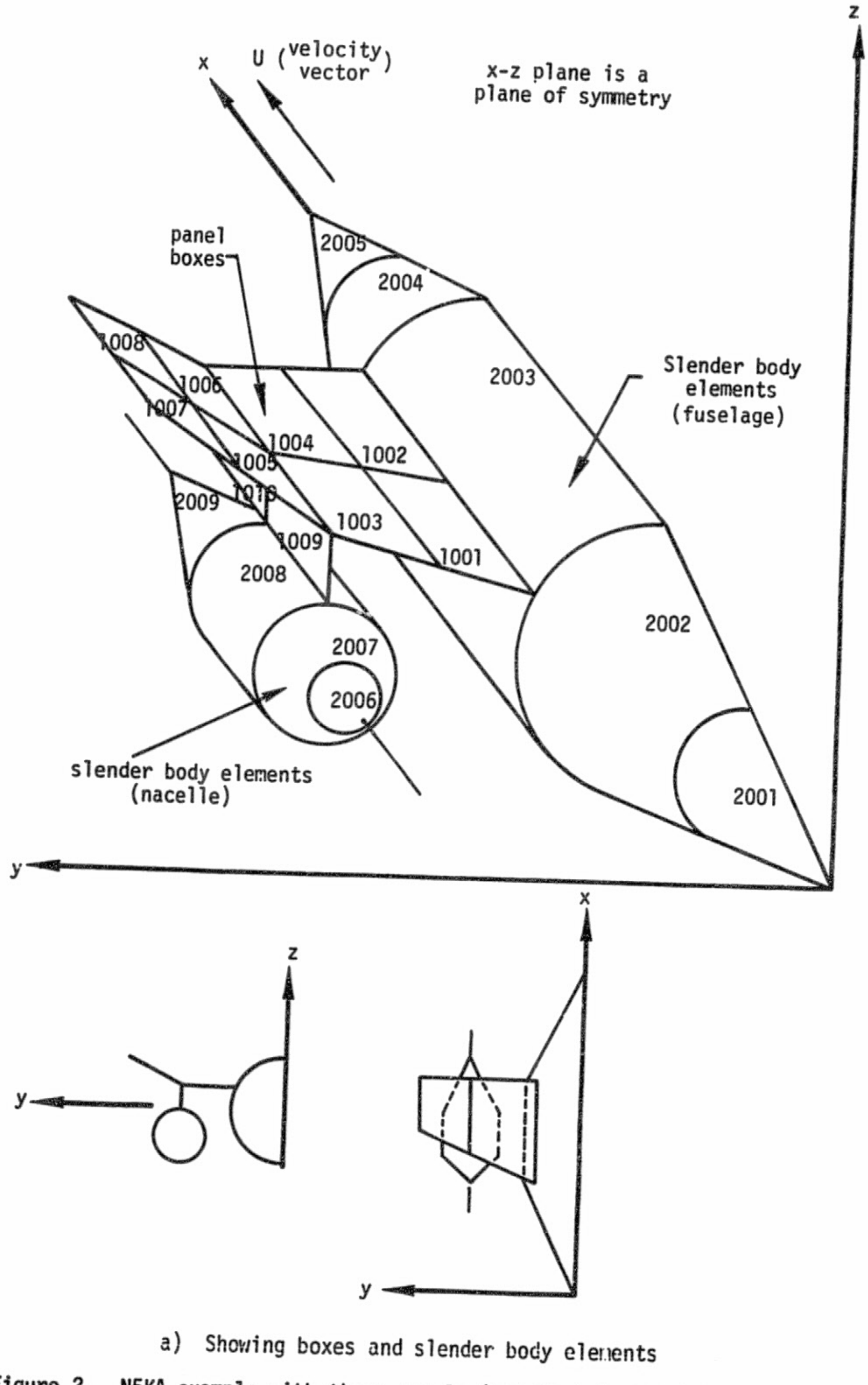
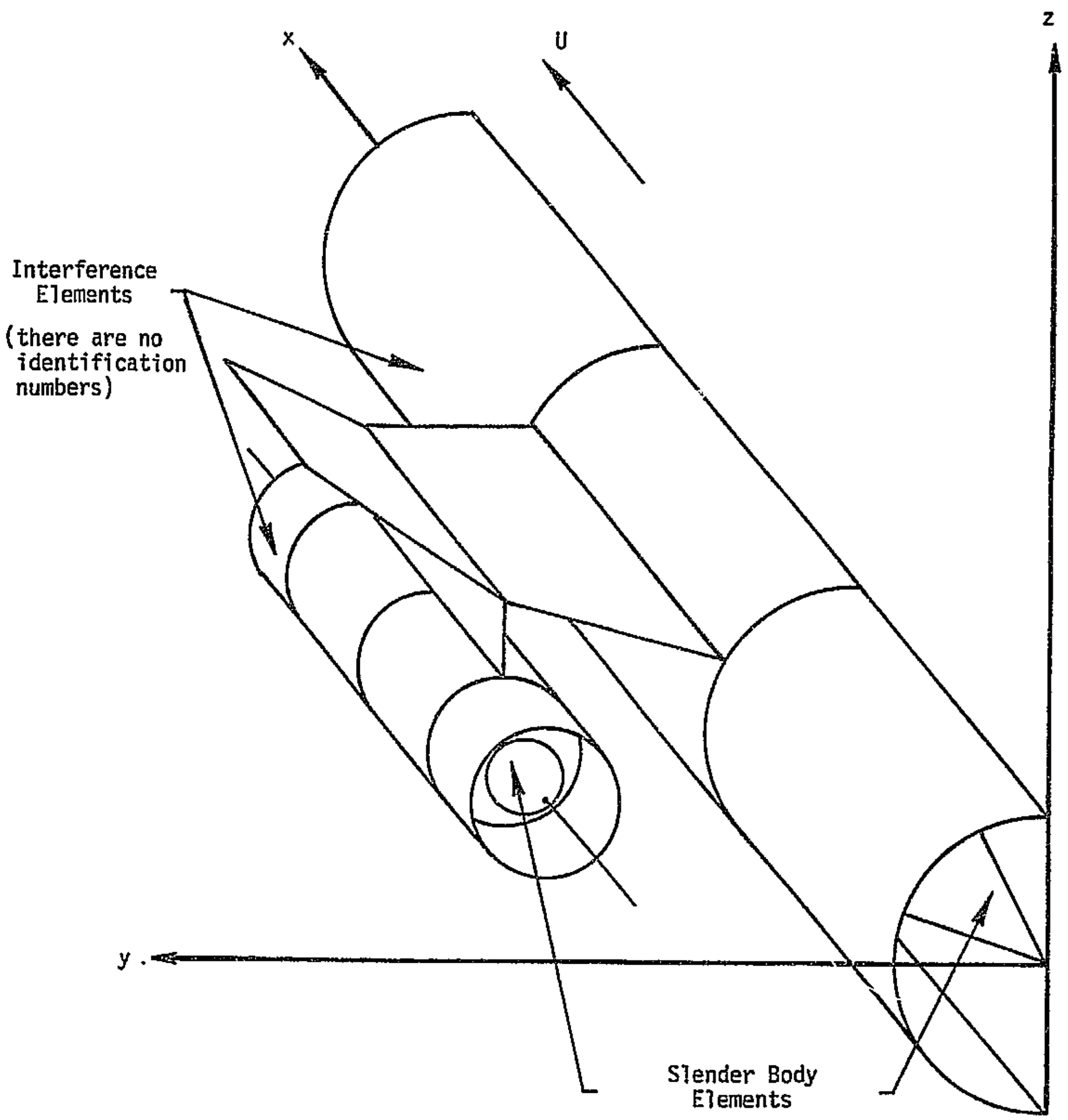


Figure 1. An aerodynamic Doublet-Lattice panel subdivided into boxes.



a) Showing boxes and slender body elements

Figure 2. N5KA example with three panels (ten boxes), two bodies (nine slender body elements), and seven interference elements.



b) Showing interference elements

Figure 2. N5KA example with three panels (ten boxes), two bodies (nine slender body elements), and seven interference elements.

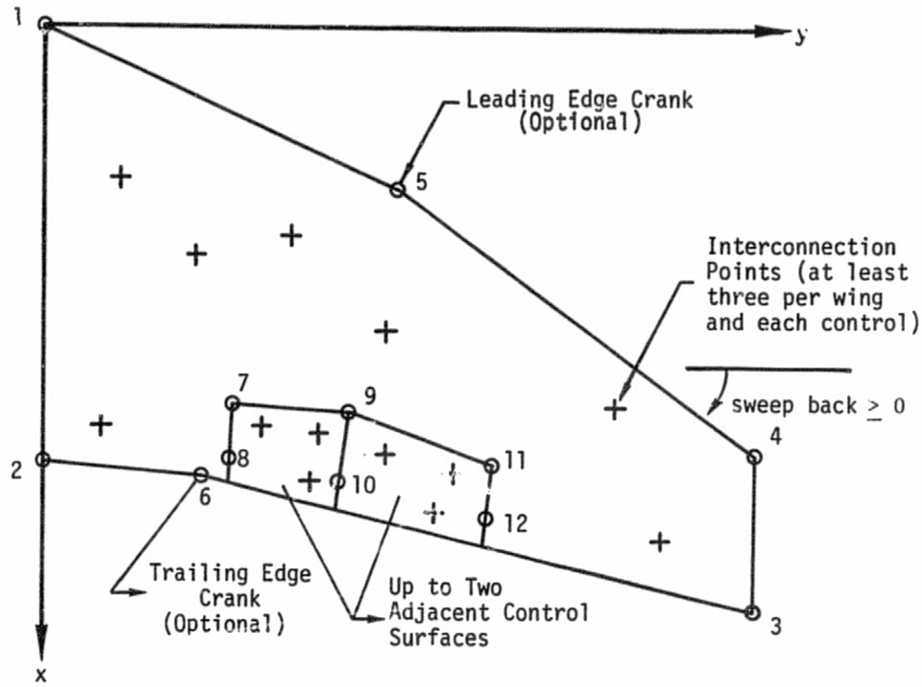
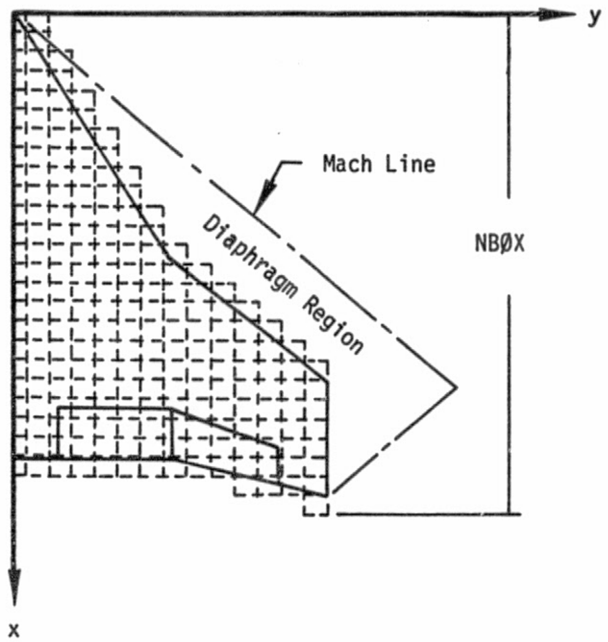


Figure 3. Mach box surface.



a) Surface as idealized

```
                    GRAPHIC DISPLAY OF REGIONS ON MAIN SEMISPAN
MACH NUMBER   1.300         BOX WIDTH     .052064         BOX LENGTH     .043248

          SS                                                S     MAIN
          SS.                                               1     CNTRL1
          SSS.                                              2     CNTRL2
          SSS..                                             .     DIAPHRAGM
          SSSS..                                            ;     WAKE
          SSSS...
          SSSSS...
          SSSSS....
          SSSSSS....
          SSSSSS.....
          SSSSSSS.....
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          SSSSSSSSSSSSSS......
          SS1111122SSSSS.....
          SS111112222SSS....
          SS1111122222SS...
          SS1111122222SS..
                    22SS.
                       S
```

b) Surface as generated by program

Figure 4. Mach box surface showing Mach boxes and diaphragm.

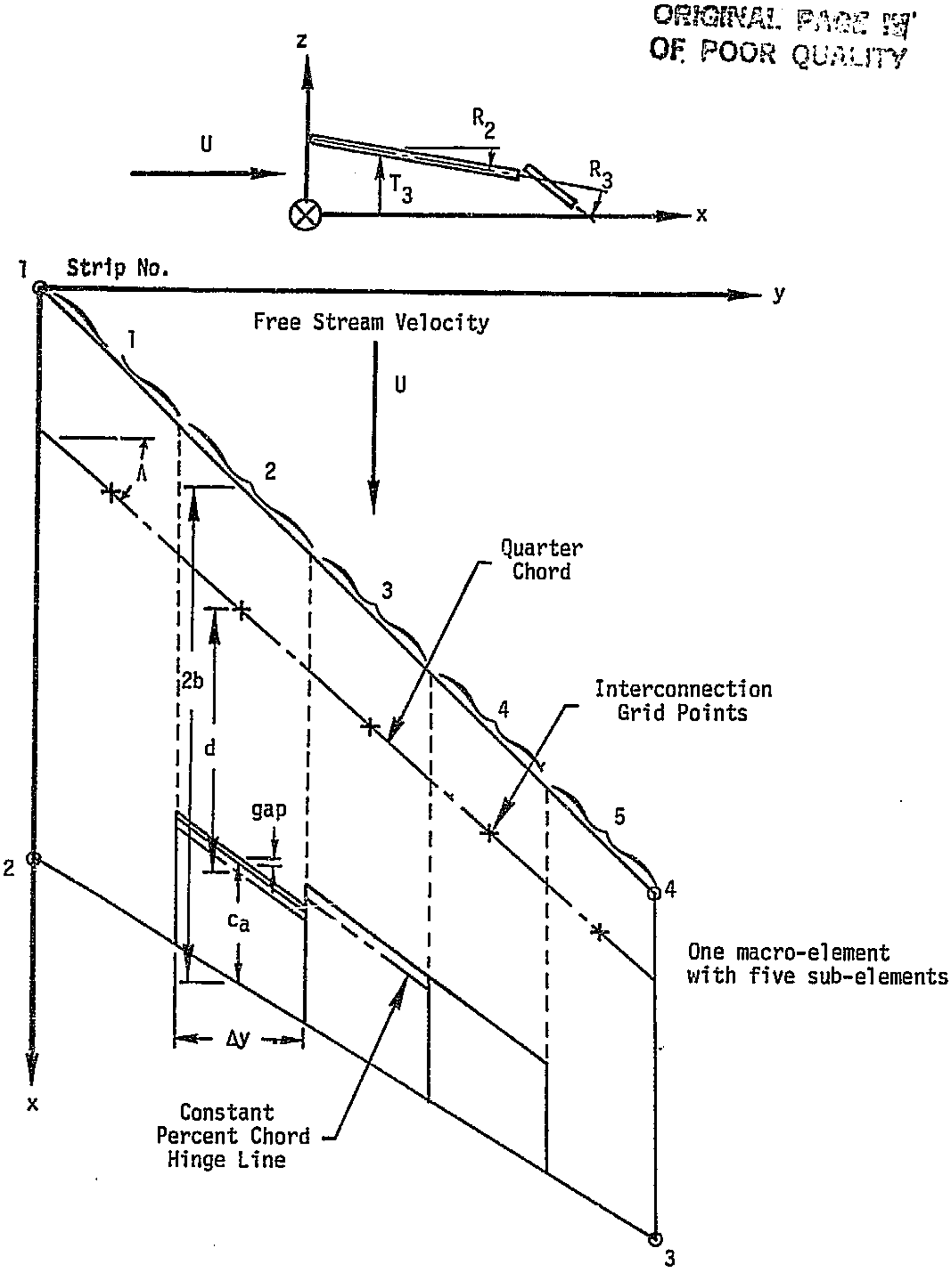

Figure 5. Strip theory example lifting surface.

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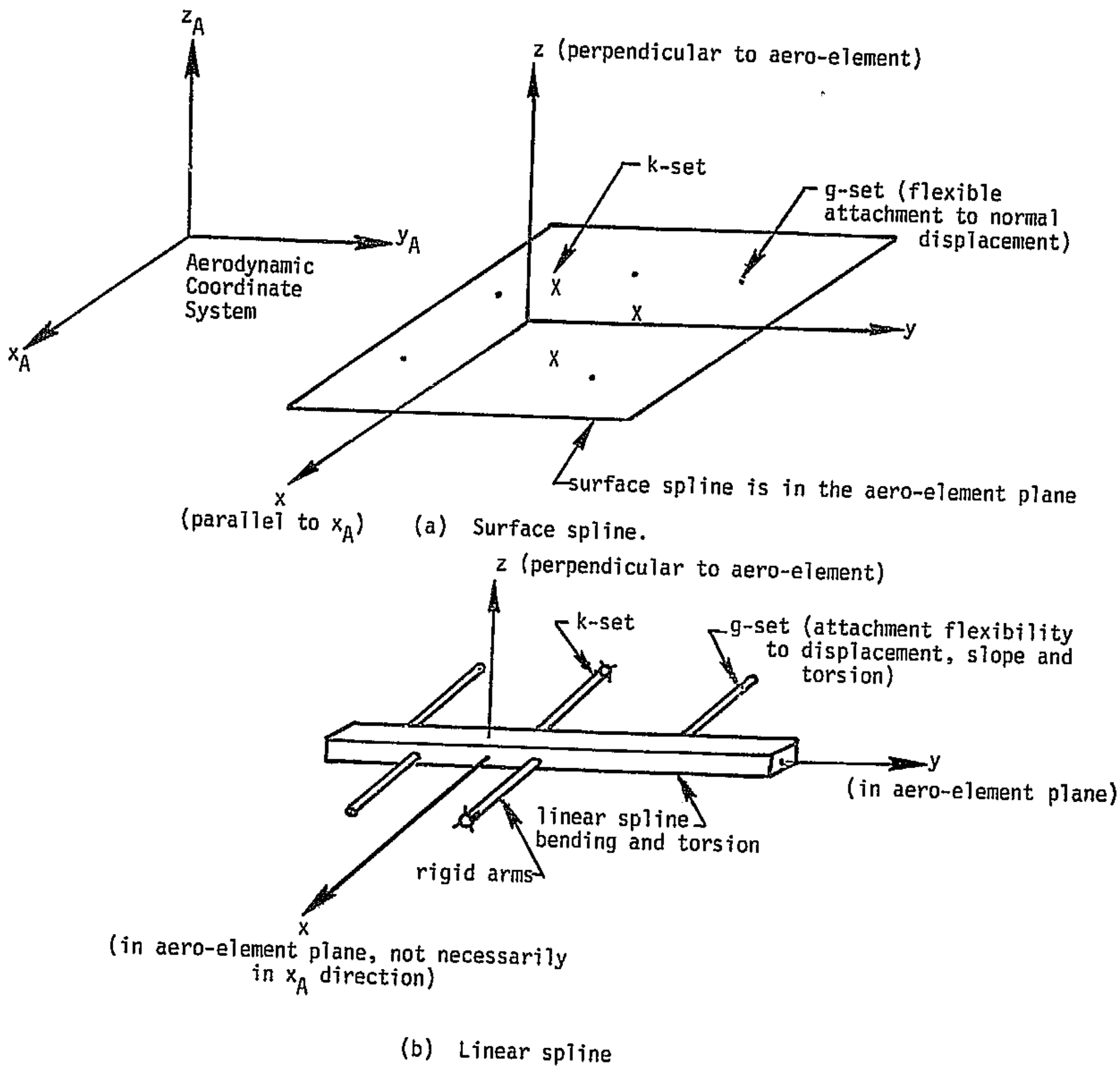

Figure 6. Splines and their coordinate systems.

Table 1. Aerodynamic elements.

Type	Doublet Lattice Panel	Lifting Body (Interference)	Mach Box Surface	Strip Theory	Piston Theory
Data Cards	CAERØ1 PAERØ1	CAERØ2 PAERØ2	CAERØ3 PAERØ3	CAERØ4 PAERØ4	CAERØ5 PAERØ5
Mach Number	Subsonic	Subsonic	Supersonic	All regimes	Hypersonic
Symmetry Options	2 planes y = 0 z = 0	2 planes y = 0 z = 0	1 plane required	None	None
Interaction	Panels and bodies in the same group		Boxes on one surface	None	None
Comments			One or two control surfaces	Control surface allowed. User may vary parameters.	A strip theory, coefficients from piston or Van Dyke theory. Control surface
Interconnection to Structure	Box centers	Slender body element centers	User specified locations	Strip 1/4-chord	Strip 1/4-chord
Displacement Components Used at Connection Points	3,5	3,5 z-bodies 2,6 y-bodies	3	3,5 No control 3,5,6 Control	3,5 No control 3,5,6 Control

Table 2. Flutter analysis methods.

	"K"	"KE"	"PK"
Structural Matrices	K (complex) B (complex) M (complex)	K (complex) M (complex)	K (real) B (real) M (real)
Aerodynamic Matrices	M (complex)	M (complex)	K (real) B (real)
User Input Loops	ρ-density m-Mach number k-reduced frequency	ρ-density m-Mach number k-reduced frequency	ρ-density m-Mach number V-velocity
Output	V-g curve Complex modes Displacements Deformed plots	V-g curve	V-g curve Complex modes Displacements Deformed plots
Method	Compute roots for user input ρ, m, k.	Compute roots for user input ρ, m, k. Reorder output so a "curve" refers to a mode.	For each ρ, m, V, iterate on each root to find consistent results. (Details in the Theoretical Manual.)
Eigenvalue Method	Several methods available, selected by user via CMETHØD in case control.	Complex Upper* Hessenberg	Real Upper* Hessenberg

* No CMETHØD card is used.

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3. Yates, E. C. and R. M. Bennett, "Use of Aerodynamic Parameters from Nonlinear Theory in Modified-Strip-Analysis Flutter Calculations for Finite-Span Wings at Supersonic Speeds;" NASA TN D-1824; July 1963.

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1.12 CYCLIC SYMMETRY

Many structures, including pressure vessels, rotating machines and antennae for space communications, are made up of virtually identical segments that are symmetrically arranged with respect to an axis. There are two types of cyclic symmetry as shown in Figures 1 and 2: simple rotational symmetry, in which the segments do not have planes of reflective symmetry and the boundaries between segments may be general doubly-curved surfaces; and dihedral symmetry, in which each segment has a plane of reflective symmetry and the boundaries between segments are planar. The use of cyclic symmetry allows the user to model only one of the identical substructures. There will also be a large saving of computer time for most problems. The theoretical treatment for cyclic symmetry is given in Section 4.5 of the Theoretical Manual.

The total model consists of N identical segments which are numbered consecutively from 1 to N. The user supplies a NASTRAN model for one segment, using regular elements and standard modeling techniques, except grid points are not permitted on the polar axis. All other segments and their coordinate systems are automatically rotated to equally spaced positions about the polar axis by the program. The boundaries must be conformable, i.e., the segments must coincide. This is easiest to insure if a cylindrical or spherical coordinate system is used, but such is not required. The PARAM card, CTYPE, is used to specify either rotational symmetry or dihedral symmetry and the number of segments, N, in the structural model is specified on the PARAM card, NSEGS. As indicated in Figure 2, dihedral symmetry provides solutions for each segment and its reflected image. This requires application of both symmetric and antisymmetric boundary conditions.

In rotational symmetry the basic transformation equation between the structure segments n = 1, 2, etc. and the harmonic indices k = 0, 1, 2, etc. is

$$u^n = \bar{u}^o + \sum_{k=1}^{KMAX} [\bar{u}^{kc}\cos(n-1)ka + \bar{u}^{ks}\sin(n-1)ka] \qquad (1)$$

where

u^n is any displacement, load, stress, etc., on the n^{th} segment (n = 1, 2...NSEGS),

$\bar{u}^o$, $\bar{u}^{kc}$, $\bar{u}^{ks}$ are the corresponding cyclic coefficients used in the solution which define the entire structure,

k is the cyclic index (i.e., KINDEX),

KMAX is the limit ($KMAX \leq \frac{N}{2}$) of k. (If all values of k are used, the transformation is exact),

and

$a = \frac{2\bar{u}}{NSEGS}$ is the circumferential angle for each segment.

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In dihedral symmetry the repeated request may be divided into two half segments divided by a plane of symmetry. The solution is obtained for symmetric motions (S) and antisymmetric motions (A) of the right half segment modeled by the user. Thus, for each cyclic index, k, four coefficients are obtained defining the variable, n, i.e., $\bar{u}^{ks,S}$, $\bar{u}^{kc,S}$, $\bar{u}^{ks,A}$ and $\bar{u}^{kc,A}$. In the right hand segment the terms are added

Right side: $$\bar{u}^{ks} = \bar{u}^{ks,S} + \bar{u}^{ks,A} \tag{2}$$

In the left hand mirror image the antisymmetric solution is subtracted.

Left Side: $$\bar{u}^{ks} = \bar{u}^{ks,S} - \bar{u}^{ks,A} \tag{3}$$

The reason for using dihedral symmetry is to reduce the size of the model by one half. However in static analysis, this procedure requires twice as many solutions as in rotational cyclic symmetry. In normal modes analysis only the modes for the symmetrical components $\bar{u}^{kc,S}$ and $\bar{u}^{ks,A}$ are obtained. The modes for the other two terms are identical and correspond to a one segment rotation of the structure.

The two boundaries are called sides 1 and 2. In the case of rotational symmetry, side 2 of segment n is connected to side 1 of segment n+1, as shown in Figure 1. In the case of dihedral symmetry, side 1 is on the boundary of the segment and side 2 is on the plane of symmetry for the segment, as shown in Figure 2. In either case the grid point numbers on sides 1 and 2 must be specified on the bulk data card, CYJØIN.

As indicated in the Theoretical Manual Section 4.5, the cyclic symmetry analysis uses a finite Fourier transformation. Hence, the use of cyclic symmetry procedures does not introduce any additional approximations beyond those normally associated with finite element analysis. In the case of static analysis, a shortened approximate method may be used where the maximum value of the harmonic index is specified on the PARAM card, KMAX. The default procedure is to include all harmonic indices. The use of a smaller number of harmonic indices is similar to truncating a Fourier series. The stiffness associated with the higher harmonic indices tends to be large, so that these components of displacements tend to be small. In the case of vibration analysis, the solutions are performed separately for each harmonic index. The harmonic index for each solution is specified on the PARAM card, KINDEX. The standard restart procedures can be used to calculate vibration modes for additional harmonic indices.

No restrictions are placed on the use of the single point constraint, the multipoint constraint, or the ØMIT feature of NASTRAN, other than that the constraints must be the same for each segment. Constraints between segments are automatically applied to the degrees of freedom

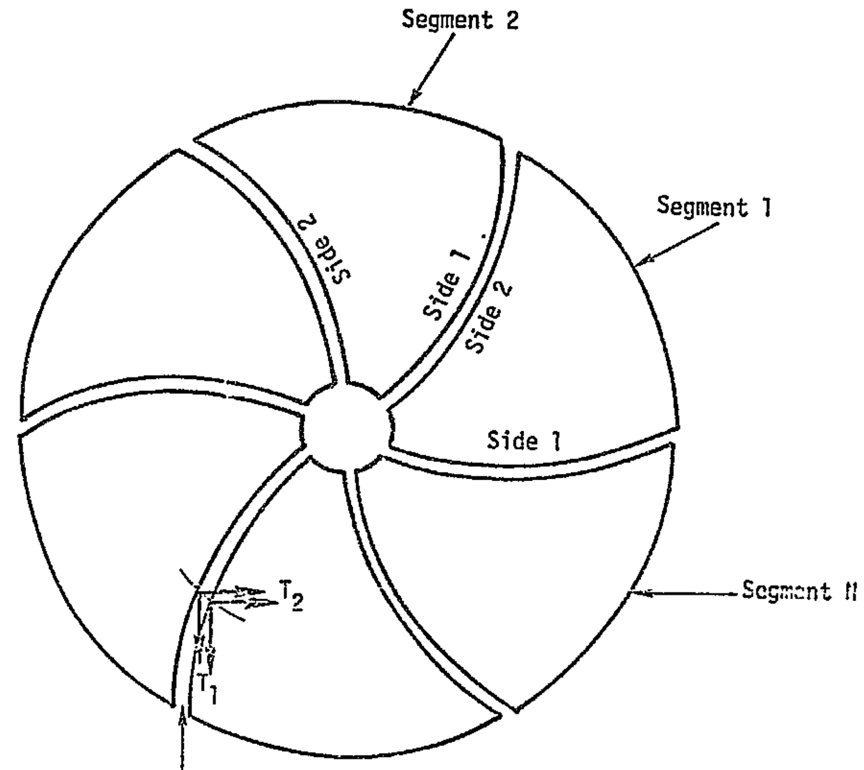
at grid points specified on CYJØIN bulk data cards which are not otherwise constrained. The SPCD bulk data card may be used to vary the magnitude of enforced displacements for each of the segments. In the case of static analysis, the ØMIT feature may be used to remove all degrees of freedom at internal grid points without any loss of accuracy. Since this reduction is applied to a single segment prior to the symmetry transformations, it can greatly reduce the amount of subsequent calculation. In the case of vibration analysis, the ØMIT feature is used in the usual way to reduce the size of the analysis set and involves the usual approximations. The SUPØRT card for free bodies cannot be used with cyclic symmetry.

Static loads are applied to the structural model in the usual way. A separate subcase is defined for each segment (half segment for dihedral symmetry) and loading condition. The subcases for static loading must be ordered sequentially, according to the segment numbers. Multiple loading conditions for each segment must be in consecutive subcases. In the case of rotational symmetry, there will be a number of subcases equal to the number of segments in the structural model for each loading condition. In the case of dihedral symmetry, there will be twice as many subcases as for rotational symmetry because of the two symmetric components. If there is more than a single loading condition, the number of loading conditions must be specified on the PARAM card, NLØAD.

An alternate procedure for specifying the static loads may be used if the transform values of the forcing functions are known. In this case, the transform values of the loads are specified directly on the usual loading cards. The PARAM card, CYCIØ, must be included in the Bulk Data Deck to indicate that cyclic transform representation rather than physical segment representation is being used for the static loads. If this option is used, the subcases must be ordered according to the symmetrical components with the cosine cases preceding the sine cases for each symmetrical component. The output quantities will also be prepared in terms of the symmetric components.

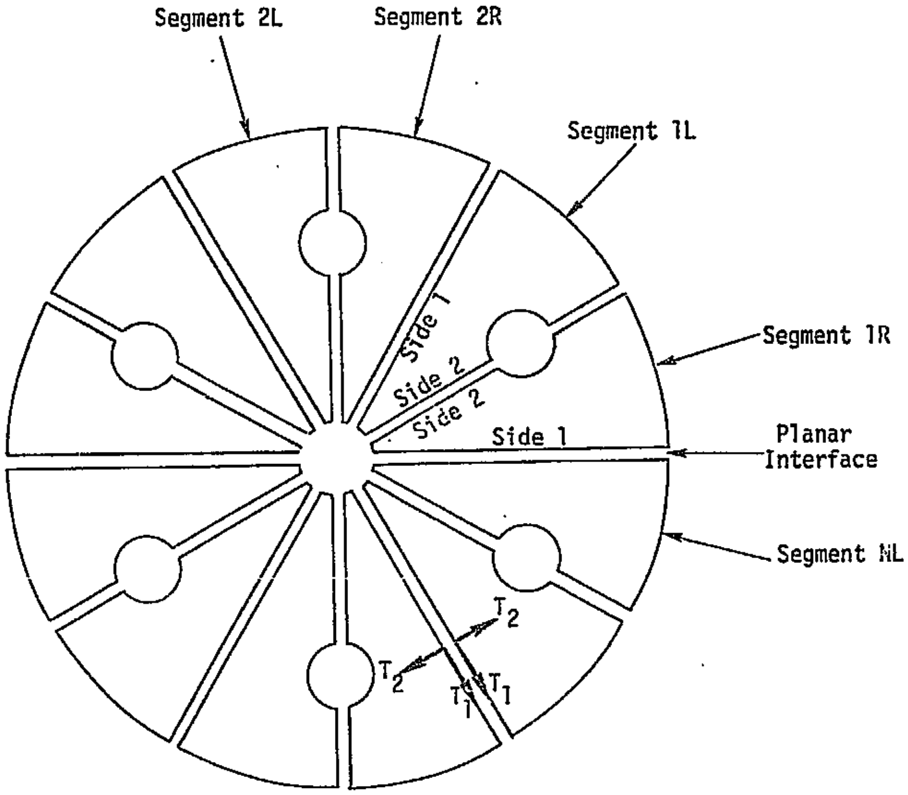
If the loading is specified in terms of the physical segments, the data reduction will also be done in terms of the physical variables. All of the normal output, including structure plots, are available. No provision is made to recover physical segment data in vibration analysis. The available output data does, however, include the symmetrical components of dependent displacements, internal forces and stresses.

For purposes of minimizing matrix bandwidth, the equations of the solution set are normally sequenced with the cosine terms alternating with the sine terms. The user may request an alternate sequence on the PARAM card, CYCSEQ, which orders all cosine terms before all sine terms. The latter may improve efficiency when all of the interior points have been omitted.



1. The user models one segment.
2. Each segment has its own coordinate system which rotates with the segment.
3. Segment boundaries may be curved surfaces. The local displacement coordinate systems must conform at the joining points. The user gives a paired list of points on Side 1 and Side 2 which are to be joined.

Figure 1. Rotational symmetry



1. The user models one-half segment (an R segment). The L half segments are mirror images of the R half segments.
2. Each half segment has its own coordinate system which rotates with the segment. The L half segments use left hand coordinate systems.
3. Segment boundaries must be planar. Local displacement systems axes, associated with inter-segment boundaries, must be in the plane or normal to the plane. The user lists the points on Side 1 and Side 2 which are to be joined.

Figure 2. Dihedral symmetry

1.13 FULLY STRESSED DESIGN

The fully stressed design option is part of the static analysis rigid format for structural analysis. Functional modules (ØPTPR1 and ØPTPR2) are provided to automatically adjust the properties based on maximum stress levels, and to control the number of design iterations based on user-supplied convergence criteria. All elements using a common property are sized together, i.e., a plate with uniform thickness remains uniform. If the user wishes to scale the properties for each element separately, each element must have its own property card. After a sufficient number of iterations, the element properties will be adjusted to the minimum values necessary to carry the prescribed loads.

The process begins by performing a static analysis for all loading conditions using the initial values for all element properties. A new property, P_2, will be scaled such that

$$P_2 = P_1\left[\frac{\alpha}{\alpha + (1-\alpha)\gamma}\right] \quad , \tag{1}$$

where P_1 is the current property value and γ is an iteration factor with a default value of unity. The scale factor, α, is defined as follows:

$$\alpha = \mathrm{Max}\left(\frac{\sigma}{\sigma_\ell}\right) \quad , \tag{2}$$

where σ is a stress value and σ_ℓ is a stress limit. The maximum value of α is taken for all loading conditions. Values of γ smaller than unity limit the property change in a single iteration, and thereby tend to improve the stability of the process. The maximum change in any property is limited by

$$K_{min} < \frac{P_2}{P_i} < K_{max} \quad , \tag{3}$$

where P_i is the initial value of the property and K_{min} and K_{max} are user-supplied limits.

Convergence is achieved by completing the user-specified number of iterations, by having all selected element properties reach the user-specified limits, or by satisfying the following convergence criteria:

$$\frac{|\sigma - \sigma_\ell|}{\sigma_\ell} < \varepsilon \quad , \tag{4}$$

where ε is a user-supplied convergence limit.

The following actions are required by the user in order to utilize the fully stressed design capability:

1. The user must select stress output in the Case Control Deck for all elements that will participate in the fully stressed design.

2. All required stress limits must be specified on the structural material cards associated with element properties that will participate in the fully stressed design.

3. The property optimization parameters must be specified on the bulk data card PØPT. This card contains user-specified values for the maximum number of iterations, the convergence criteria (ε), the iteration factor (γ), and output options to print and/or punch the calculated values of the element properties.

4. The property optimization limits (K_{min} and K_{max}) must be specified on the PLIMIT bulk data card if the user wishes to limit the maximum and minimum values of the element properties.

The detailed definitions of the scale factors for each of the element types are given in Table 1. The symbols σ_t, σ_c and σ_s represent the limiting stress values in tension, compression and shear, given on the structural material cards. All of the properties listed for each element are scaled in the same way, i.e., both the area and torsional constant for the RØD are modified using the same scale factor.

Table 1. Scale Factors for Fully Stressed Design

Element	Stress Value Used	Scale Factor (α)	Properties Changed
RØD TUBE	Axial Tension (σ_1) Axial Compression (σ_2) Torsion (τ)	$\text{Max}\left(\frac{\sigma_1}{\sigma_t}, \frac{\sigma_2}{\sigma_c}, \frac{\tau}{\sigma_s}\right)$	Area (A) Torsional Constant (J)
BAR	Fiber Stress Tension: End a (σ_{a1}), End b (σ_{b1}) Fiber Stress Compression: End a (σ_{a2}), End b (σ_{b2})	$\text{Max}\left(\frac{\sigma_{a1}}{\sigma_t}, \frac{\sigma_{b1}}{\sigma_t}, \frac{\sigma_{a2}}{\sigma_c}, \frac{\sigma_{b2}}{\sigma_c}\right)$	Area (A) Torsional Constant (J) Moments of Inertia (I_1, I_2, I_{12})
TRMEM QDMEM	Principal Tension (σ_1) Principal Compression (σ_2) Maximum Shear (τ_m)	$\text{Max}\left(\frac{\sigma_1}{\sigma_t}, \frac{\sigma_2}{\sigma_c}, \frac{\tau_m}{\sigma_s}\right)$	Thickness (t)
TRPLT QDPLT TRBSC	Same as Above (Fiber Distances z_1 & z_2)	Same as Above	Moment of Inertia (I)
TRIA1 QUAD1	Same as Above	Same as Above	Moment of Inertia (I) Membrane Thickness (t_1)
TRIA2 QUAD2	Same as Above	Same as Above	Thickness (t)
SHEAR	Maximum Shear (τ_m)	$\frac{\tau_m}{\sigma_s}$	Thickness (t)

1.14 THE CONGRUENT FEATURE

1.14.1 Introduction

An important step in any NASTRAN problem is the generation of element matrices (stiffness, mass and damping matrices, as required) in the EMG (Element Matrix Generator) module. In many cases, this step can represent a significant portion of the total problem activity. Because of the differences in algorithms and procedures, the cost of generating the element matrices for an element depends on the element type, its configuration and its properties. However, this cost is associated primarily with CPU activity and is not significantly affected by core size or I/O transfers (see Section 14.3.2 of the User's Guide).

Normally, the element matrices are generated in the EMG module once for each element in the model. However, when two or more elements in the model have the same element matrices, there is no reason why the same matrices should be computed separately for each such identical element. By declaring such elements as congruent, it is possible to cause their element matrices to be computed only once for all elements in the congruent set instead of their being computed repeatedly for each of the individual elements in the set. This results, in general, in a saving of CPU time in the EMG module. In many cases, judicious formulation of the problem to facilitate the use of the congruent feature can result in substantial savings in the computational effort. In some problems, over 99 percent reductions in EMG module CPU times have been obtained.

1.14.2 Congruent Feature Usage

The congruent feature is specified in NASTRAN by means of one or more CNGRNT cards in the Bulk Data Deck (see Section 2.4). Any number of such cards may be employed.

The CNGRNT bulk data card is an open-ended card and requires the specification of a primary element identification number and one or more secondary element identification numbers. The terms primary and secondary as used with regard to congruent data are purely relative and have no real significance. Generally, the primary element is the lowest numbered element in the congruent set, but this need not be so. The element matrices are actually computed in the EMG module only for the lowest numbered element in a congruent set (even though this element may not be the primary element). The element matrices for the rest of the elements in the congruent set are then derived from these computed matrices.

When using CNGRNT cards, the user should be aware of the following important characteristics of the congruent capability software design in NASTRAN:

- User Responsibility for Congruency Specification

The elements declared as congruent must have characteristics (such as their orientation and geometry) that cause their element matrices in the global coordinate system to be truly identical. The program cannot test the validity of this structural specification. It is, therefore, the user's responsibility to ensure that element congruence specifications are valid. Improper congruence specifications will result in an improper structure definition and will in turn lead to erroneous results. It should be emphasized that the proper use of the congruent feature will not cause the answers to be any different from those obtained without the use of the feature, but will only result in a saving of CPU time in the EMG module.

- Flexibility in Specifying Congruencies

Clearly, congruency by its very definition can apply only to elements of the same type. Thus, for instance, a bar element can be congruent only to another bar element and not to a plate element. However, because of the effective manner in which the congruent feature has been incorporated into NASTRAN, elements of different types can be specified on the same logical CNGRNT card without in any way making the different element types congruent. Thus, on the same logical CNGRNT card, several bar elements can be declared as belonging to a congruent set and several plate elements can be specified as belonging to a separate congruent set. However, the user should ensure that such specifications do not lead to erroneous declarations when elements of different types have the same identification numbers.

- Provision of "Phantom" Element Identification Numbers

As a corollary to the above, it may be noted that the element identification numbers (primary or secondary) specified on a CNGRNT card need not all exist in a model. This greatly facilitates the use of the THRU option on the card. However, the user should be cautioned that, if too many non-existent elements are specified in the CNGRNT data (as may be the case when the THRU option is used), the EMG module may not have enough core to process all the CNGRNT data. In that case, an appropriate message is issued and those elements whose CNGRNT data cannot be processed will have their element matrices computed separately.

1.14.3 Factors Affecting Congruent Feature Efficiency

As indicated earlier, the use of the congruent feature results in increased computational efficiency. The degree of efficiency obtained depends on the following factors some of which can be influenced by the user input specifications:

- Number of Congruent Elements

Clearly, the larger the number of elements in a congruent set and the larger the number of sets, the higher the savings in CPU time.

- Type of Elements Specified as Congruent

Larger savings in CPU time are obtained for certain element types than for other element types. Thus, for instance, declaring two IHEX3 elements as congruent will result in more savings than declaring two IHEX1 elements as congruent.

- Type of Analysis

For a specified congruent set, larger savings are obtained in dynamic analysis than in static analysis since, in the former, mass and/or damping matrices need to be computed in addition to stiffness matrices.

- Numbering of Grid Points of the Congruent Elements

Processing is slightly more efficient if the relative order of the numbering of the grid points of the congruent elements is the same. Thus, for instance, two congruent quadrilateral plate elements are processed more efficiently if their grid points are numbered 1-7-4-6 and 12-23-16-20, respectively, than if they were numbered 1-7-4-6 and 11-14-27-15, respectively. In the former case, the grid point numbers of the two congruent elements increase or decrease in the same order as we go around the elements. In the latter case, the grid point numbers of the two congruent elements increase or decrease in different orders as we go around the elements.

1.14.4 Examples of Congruent Feature Usage

The congruent feature is currently employed in fifteen (15) of the NASTRAN demonstration problems. A comparison of the EMG module CPU times (on IBM S/360-95 computer) for these problems with and without the congruent feature is presented in Table 1. The savings resulting from the use of the congruent capability are quite apparent from this table. The most dramatic savings are obtained in NASTRAN Demonstration Problem Nos. 3-1-2 and 8-1-2 in which the EMG module CPU times are reduced by more than 99 percent.

Table 1. Examples of Congruent Feature Usage in NASTRAN Demonstration Problems

Example No.	Demonstration Problem No.	Congruent Element Data			EMG Module CPU Times (sec.)*		Saving in EMG Module CPU Time Obtained by Using the Congruent Feature (%)
		Element Type	Number of Elements	Number of CNGRNT Sets	Using the Congruent Feature (a)	Without Using the Congruent Feature (b)	$\frac{(b)-(a)}{(b)} \times 100$
1	1-3-1	QDMEM	216	1	0.8	8.3	90.4
2	1-3-2	QDMEM1	216	1	1.2	13.5	91.1
3	1-3-3	QDMEM2	216	1	1.5	11.1	86.5
4	1-8-1	HEXA1	40	1	0.1	3.5	97.1
5	1-9-1	HEXA2	40	1	0.3	7.4	95.9
6	1-11-1	QUAD1	50	1	0.2	7.7	97.4
7	1-13-1	IHEX1	40	5	2.8	16.9	83.4
8	1-13-2	IHEX2	2	1	2.7	4.5	40.0
9	3-1-1	QUAD1	200	1	0.4	15.4	97.4
10	3-1-2	QUAD1	800	1	0.8	130.5	99.4
11	5-1-1	TRIA1	80	4	0.7	11.7	94.0
12	8-1-1	QUAD1	100	1	0.4	5.8	93.1
13	8-1-2	QUAD1	400	1	0.4	49.1	99.2
14	14-1-1	QUAD2	10	5	1.7	2.3	26.1
15	15-1-1	BAR QUAD2	10 20	5 5	1.4	5.0	72.0

*All of the above problems were run on the IBM S/360-95 computer.

1.15 MAGNETIC FIELD PROBLEMS

1.15.1 Introduction

The determination of the magnetic fields in and about ferromagnetic bodies is an important step in the design of many structures and components. In commercial applications, knowledge of the fields in and near transformers and electrical machinery is often desired because of their effect on performance. This is discussed further in Reference 1.

1.15.2 Theory

The governing equations of classical electromagnetic wave theory are Maxwell's equations:

$$\nabla \cdot D = \rho \tag{1}$$

$$\nabla \cdot B = 0 \tag{2}$$

$$\nabla \cdot E = -\frac{\partial B}{\partial t} \tag{3}$$

$$\nabla \cdot H = J + \frac{\partial D}{\partial t} \tag{4}$$

where D = electric displacement vector,

B = magnetic flux density vector,

E = electric field intensity vector,

H = magnetic field intensity vector,

J = current density vector,

P = charge density, and

t = time.

Additional relations are:

$$D = \varepsilon E$$

$$J = \sigma E$$

and $B = \mu H$

where

ε = permittivity,

σ = conductivity, and

μ = magnetic permeability.

The present work is concerned only with time-independent fields, thereby decoupling Equations 1 through 4 into one pair of equations governing the electrostatic field (Equations 1 and 3) and a second pair governing the magnetostatic field (Equations 2 and 4). Interest here is in the latter pair and the appropriate constitutive equations:

$$\nabla \cdot B = 0 \tag{5}$$

$$\nabla \cdot H = J \tag{6}$$

with $$B = \mu H \tag{7}$$

Numerical techniques for solving Equations 5 through 7 include integral equations and differential equations. The present work uses the differential equation approach incorporated into NASTRAN.

In the theoretical aspects of the analysis, ϕ is defined as the scalar potential of the magnetic field anomaly H_m i.e.,

$$H_m = \nabla \phi \tag{8}$$

where H_m is the modification, or anomaly, due to the presence of ferromagnetic material, to a Biot-Savart field. It is ϕ that is solved for by using the heat transfer approach in NASTRAN.

In the anticipated applications of this method, accurate values of ϕ will be required in both the near field and far field. A major drawback of using the finite element method for solving magnetostatic problems is that the infinite domain surrounding the ferromagnetic material must be modeled (at least, to the point at which ϕ may be considered small). These accuracy and modeling requirements mean that the finite element mesh must be very fine in all regions. In addition, the results near the finite element boundary may not be as precise as desired because of the imposed $\phi = 0$ boundary condition.

Two methods which could avoid the need for modeling the vast majority of the exterior domain are the use of infinite elements and the coupling of integral and differential techniques. These methods are presently being investigated, but, meanwhile, a third method, harmonic expansions, is being used to avoid fine modeling to "infinity". In the present applications, all ferromagnetic material and sources are enclosed by a suitably shaped surface, usually spherical or prolate spheroidal. Then, NASTRAN is used to solve for the potentials at the grid points on the enclosing surface. Finally, Laplace's equation

$$\nabla^2 \phi = 0 \tag{9}$$

may be solved, in the proper coordinates, using the potentials on the enclosing surface as an interior boundary condition.

1.15.3 Prolate Spheroidal Harmonic Expansion

Most applications require only prolate spheroidal coordinates. The solution of Laplace's equation in these coordinates is

$$\phi(\xi,\eta,\theta) = \sum_{n=0}^{\infty}\sum_{m=0}^{n}\left[A_{mn}\cos(m\theta) + B_{mn}\sin(m\theta)\right]P_n^m(\eta)\left[\frac{Q_n^m(\xi)}{Q_n^m(\xi_o)}\right]$$

where
- ϕ = reduced magnetic scalar potential
- ξ,η,θ = prolate spheroidal coordinates
- ξ_o = coordinate of the interior prolate spheroidal surface
- P_n^m, Q_n^m = Legendre functions of the first and second kinds, respectively

(10)

$$\left.\begin{matrix} A_{mn} \\ B_{mn} \end{matrix}\right\} = \frac{\epsilon_m}{4\pi}(2n+1)\frac{(n-m)!}{(n+m)!}\int_0^{2\pi}\begin{matrix}\cos\\ \sin\end{matrix}(m\theta)d\theta\int_{-1}^{+1}\phi_o(\eta,\theta)P_n^m(\eta)\,d\eta$$

$$\epsilon_m = \begin{cases} 1, & m = 0 \\ 2, & m > 0 \end{cases}$$

$\phi_o(\eta,\theta)$ = distribution of potential ϕ on prolate spheroidal surface $\xi = \xi_o$

With the use of this expansion, the finite element model can become coarser as the distance from the prolate spheroidal reference surface increases. In addition, the model need not extend "too far", since the concept requires an accurate potential distribution only on the reference surface, which is placed as close as possible to the ferromagnetic material. However, the discretization of the reference surface itself must be fine enough to allow for an accurate representation of the integrals in the computation of the coefficients A_{mn} and B_{mn}.

1.15.4 Input Data for Magnetostatic Analysis

This section provides user information needed to perform a magnetostatic analysis with NASTRAN. This information is divided into six parts: NASTRAN card, Executive Control Deck, Case Control Deck, Bulk Data Deck, Data cards with Different Meanings and Output.

1.15.4.1 NASTRAN Card

In magnetostatic problems, functional module SSG1 (Static Solution Generator - Phase 1) generates a data block, HCFLD, that contains the source magnetic field at each grid point for each subcase resulting from specified fields on the SPCFLD bulk data card (see Section 1.15.4.4). Since

HCFLD is not used in subsequent functional modules and is generated only for informational purposes, the costlier computation of grid point source magnetic fields due to current coils and dipoles is left as an option to the user. If these fields are to be computed for HCFLD, the NASTRAN card must contain MØDCØM (9) = 1.

1.15.4.2 Executive Control Deck

Magnetostatic analysis is performed by using the steady-state heat transfer capability (Rigid Format 1, Approach HEAT) in NASTRAN. Therefore, the Executive Control Deck must contain the following two cards:

1. APP HEAT
2. SØL 1

In addition, there are three functional modules that pertain specifically to magnetostatic analysis, but are not incorporated into the Rigid Format. These are briefly described below:

1. Module EMFLD computes the total field intensity and flux density of user-selected finite elements. It reads the anomaly field information (temperature gradients) which NASTRAN computes in element coordinate systems, transforms it to the basic coordinate system, and adds the results to the element centroidal source magnetic fields computed in functional module SSG1.
2. Module MAGBDY processes bulk data card PERMBDY (see Section 1.15.4.4) and converts the grid points on the card to a form more readily usable by functional module SSG1.
3. Module PRØLATE computes the prolate spheroidal harmonic coefficients to be used by an interactive graphics program.

In order to execute the above modules and perform certain tasks related to the data blocks output from functional module SSG1, the following ALTER statements to the Rigid Format are required:

```
ALTER  n1 $ (where n1 = DMAP statement number of LABEL HLBL7, just before SSG1 module)
MAGBDY GEØM1, HEQEXIN/PER/V,N,IPG $
ALTER  n2 $ (where n2 = DMAP statement number of SDR1 module)
SDR1,    ,HCFLD,,,,,,,,,/,HCFLDG,/V,N,NSKIP/STATICS $
SDR1,    ,HCCEN,,,,,,,,,/,HCCENG,/V,N,NSKIP/STATICS $
SDR1,    ,REMFLD,,,,,,,,,/,REMFLG,/V,N,NSKIP/STATICS $
ALTER  n3 $ (where n3 = DMAP statement number of SDR2 module)
EMFLD    HØEF1,HEST,CASECC,HCFLDG,MPT,DIT,REMFLG,GEØM1,CSTM,HCCENG/HØEH1/V,N,HLUSET $
```

```
ALTER    n4 $ (where n4 = DMAP statement number of ØFP module, just after SDR2 module)
ØFP      HØEH1,,,,,//S,N,CARDNØ $
PRØLATE  GEØM1,HEQEXIN,BGPDT,CASECC,NSLT,HUGV,REMFLG,HEST,MPT,DIT/PRØCØF $
ØUTPUT2  PRØCØF,,,,//0/11 $
TABPT    PRØCØF,,,,// $
ENDALTER $
```

The ØUTPUT2 functional module writes prolate spheroidal coefficient information to FØRTRAN-readable file UT1, which can be used as input to an interactive graphics post-processor. The TABPT instruction prints that file for user inspection.

1.15.4.3 Case Control Deck

The FØRCE (or ELFØRCE) card is an optional request used to output the finite element anomaly and total magnetic fields. The anomaly field is output in the element coordinate system, the total field intensity is output in the basic coordinate system, and the total flux density is output in the coordinate system given on the BFIELD bulk data card (see Section 1.15.4.4). The basic coordinate system is the default.

In order to output the total magnetic field for an element, the source and anomaly magnetic fields must be computed for the element, usually at the centroid. Since the number of elements in a magnetostatic analysis is usually large, care should be taken in requesting this output for a significant number of elements.

The AXISYMMETRIC (or AXISYM) card is used in conjunction with the PRØLATE bulk data card (see Section 1.15.4.4) to indicate symmetric or antisymmetric boundary conditions (or lack thereof). Symmetry and antisymmetry conditions refer to the source magnetic field (applied to a symmetric finite element model) and, therefore, to the anomaly potential with respect to the X-Y plane of the coordinate system which must be used when prolate spheriodal harmonic coefficients are to be computed. The options for AXISYM are:

Option	Meaning
SYMM	Symmetry conditions, and the source magnetic field for this subcase will be included in the prolate spheroidal harmonic expansion.
SYMMANØM	Symmetry conditions, and the source magnetic field for this subcase will not be included in the prolate spheroidal harmonic expansion.

ANTI	Antisymmetric conditions, and the source magnetic field for this subcase will be included in the prolate spheroidal harmonic expansion.
ANTIANØM	Antisymmetric conditions, and the source magnetic field for this subcase will not be included in the prolate spheroidal harmonic expansion.
ANØM	Neither symmetry nor antisymmetry. Also, the source magnetic field for this subcase will not be included in the prolate spheroidal harmonic expansion.
No option (card does not appear)	Neither symmetry nor antisymmetry. Also, the source magnetic field for this subcase will be included in the prolate spheroidal harmonic expansion.

The specification of SYMM, SYMMANØM, ANTI or ANTIANØM implies that the structure is symmetric with respect to the X-Y plane of the required coordinate system and that only one half, or 180°, of the structure and surrounding medium is modeled. If ANØM or no specification is made, then full 360° modeling is assumed.

The use of ANØM, with or without SYMM and ANTI, means that only the anomaly potential and anomaly field will be available for that subcase from the prolate spheroidal harmonic expansion. Requiring only the anomaly results is often the situation when the Earth's magnetic field is the source field. When a current coil is the source, the total potential and field are usually needed, in which case ANØM would be omitted.

1.15.4.4 Bulk Data Deck

There are eight bulk data cards that pertain specifically to magnetostatics analysis. A brief description of each card follows.

1. The BFIELD card specifies a coordinate system identification number in which the total flux density for selected elements will be output. (The basic coordinate system is the default.) The anomaly field intensity is output in the element coordinate system, the total field intensity in the basic coordinate system, and the total flux density in the coordinate system specified by BFIELD.

2. The CEMLØØP card defines a circular current coil. The orientation of the coil is defined by specifying coordinates of the center of the coil and coordinates of two points on its circumference. The magnetic field due to the coil is computed from the Biot-Savart law using an elliptic integral formulation.
3. The GEMLØØP card defines a general current coil in piecewise linear segments by specifying the coordinates of the endpoints of the segments. At most, 14 linear segments are allowed on one logical GEMLØØP card, but the segments can be continued on another card.
4. The MDIPØLE card defines a magnetic dipole moment by specifying the coordinates of the location of the dipole and the components of its moment. The resulting magnetic field intensity is computed only at those points whose distances from the dipole are within ranges defined on the MDIPØLE card.
5. The PERMBDY card specifies points on boundaries of dissimilar magnetic permeability. The purpose of this card is two-fold: to reduce computer run time and to avoid numerical errors which may occur due to limited orders of numerical integration, nonuniform modeling, use of CTETRA elements, etc. Such numerical errors may occur as follows: the magnetic equivalent loading at a point, resulting from a single finite element, is given by the equation:

$$f_i = \int_V (\nabla N_i)^T \; \mu H_c dV \qquad (11)$$

It can be shown that, if a point is surrounded by elements of the same magnetic permeability μ, then f_i at the point must be 0. (The integral of Equation 11 is obtained from an integration by parts of $\int_V N_i\,(\nabla\mu \cdot H_c)dV$, which is zero in areas of uniform permeability.) However, due to various combinations of circumstances involving both numerical and modeling techniques, f_i may be nonzero in areas of uniform permeability, and, in fact, may be significant compared with the loading at points which are connected to elements of different permeabilities, thus degrading the results. The presence of PERMBDY causes NASTRAN to compute equivalent loads only at the grid points of the PERMBDY card. Therefore, if this card is used, it must contain all appropriate points. In this way, the presence of PERMBDY improves numerical accuracy as well as computational efficiency.

6. The PRØLATE card defines a prolate spheroidal surface in the finite element model, which is used to compute coefficients of a prolate spheroidal harmonic expansion of the anomaly or total scalar potential.

   When the PRØLATE card is used, NASTRAN assumes an orientation of the generating ellipse of the prolate spheroidal surface with respect to the basic coordinate system. Therefore, the center of the ellipse is assumed to coincide with the origin of the basic coordinate system, the major axis of the ellipse is assumed to coincide with the X-axis of the basic coordinate system, and the minor axis is assumed to coincide with the Y-axis of the basic coordinate system. In addition, the aximuthal original of the _ component of the prolate spheroidal coordinate system is the X-Y plane, with the direction of rotation following the right-hand rule about the X-axis. This assumption does not preclude the definition of other right-handed coordinate systems with which the locations of grid points may be defined.

7. The REMFLUX card specifies remanent flux density for selected elements. Since NASTRAN handles only linear materials, it cannot follow the hysteresis loop of a magnetization curve. However, as long as the section of interest of the magnetization curve is approximately linear, REMFLUX may be used to specify nonzero remanence.

8. The SPCFLD card is used to specify components of source magnetic field intensity at selected grid points. One use of this card is to specify the Earth's magnetic fields.

1.15.4.5 Data Cards with Different Meanings

In a standard NASTRAN steady-state heat transfer analysis, the basic unknown in the problem is the temperature at each grid point. In a magnetostatic analysis, the basic unknown is the anomaly potential V_m. Therefore, any NASTRAN data card or output which refers to degrees-of-freedom refers to the anomaly, or reduced, scalar potential. Some examples are bulk data cards SPC and SPC1, Case Control card THERMAL (or DISPLACEMENT, which is a carryover from structural analysis), and TEMPERATURE output.

Two other bulk data cards for which the meanings are different are material cards MAT4 and MAT5. In heat transfer, these cards contain thermal conductivity values. In magnetostatics, they specify magnetic permeability.

1.15.4.6 Output

The output available from a magnetostatic analysis is similar to that from a heat transfer analysis. The temperature output obtained from a DISPLACEMENT or THERMAL request must be interpreted as anomaly potential output. The load vector output obtained from the ØLØAD request is the magnetic equivalent load. The temperature gradient and flux output resulting from a FØRCE or ELFØRCE request should be interpreted as anomaly magnetic field intensity and anomaly flux density, respectively. These vectors are output in the element coordinate system. In addition, the FØRCE or ELFØRCE request also generates total finite element magnetic field and induction output. The magnetic field intensity is output in the basic coordinate system, and the magnetic flux density or induction is output in a coordinate system specified on a BFIELD bulk data card.

Finally, the file of prolate spheroidal harmonic coefficient information is available for inspection. This file is contained in data block PRØCØF. The TABPT statement needed to print PRØCØF is given in Section 1.15.4.2.

STRUCTURAL MODELING

REFERENCE

1. Hurwitz, M. M., and Brooks, E. W., "The Solution of Magnetostatic Field Problems with NASTRAN," David W. Taylor Naval Ship Research and Development Center, DTNSRDC-82/106, December 1982.

1.16 DYNAMIC DESIGN-ANALYSIS

1.16.1 Introduction

The Dynamic Design-Analysis Method (DDAM) is the standard procedure for shock design of equipment. Often, the equipment is first analyzed using NASTRAN. The data and results must then be converted into other forms for use in DDAM. Incorporating DDAM into NASTRAN has enabled the entire process to be performed more efficiently. (The details of the implementation of DDAM into NASTRAN are described in Reference 1.)

1.16.2 Theory

The steps of the DDAM procedure are described here very briefly. A more complete description is given in Reference 2.

Step 1. Compute natural frequencies and mode shapes. (Rigid Format 3, Approach DISP)

Step 2. Compute the participation factor for each mode:

$$P_a = \frac{\sum_i M_i X_{ia}}{\sum_i M_i X_{ia}^2} \tag{1}$$

where M_i is the mass of the i^{th} degree-of-freedom and X_{ia} is the i^{th} component of the a^{th} mode shape.

It is assumed that only those terms of $\{X_a\}$ that correspond to a particular direction are used in Equation 1. That is, the a^{th} mode may have three participation factors associated with it, one for each orthogonal direction.

The numerator of Equation 1 may be written as (considering all computed modes):

$$[\phi]^T [M] [V] \tag{2}$$

where $[\phi]$ = matrix of eigenvectors (mode shapes), order n x m, with n = order of the problem, m = number of modes computed;

$[M]$ = mass matrix, order n x n; and

$[V]$ = direction cosine matrix, order n x ℓ with ℓ = 1, 2, or 3, the number of desired directions.

Typically, [V] may consist of 1's and 0's which "pick off" desired directions. However, that form is not necessary and any consistent set of direction cosines may be used.

The denominator of Equation 1 may be written as (considering all computed modes)

$$[\phi]^T \; [M] \; [\phi] \tag{3}$$

which is the diagonal modal mass matrix. Therefore, Equation 1 may be written as

$$[P_a]_{m \times \ell} = [\mathrm{diag}\,([\phi]^T[M][\phi])]^{-1} \; [\phi]^T \; [M] \; [V] \tag{4}$$

<u>Step 3.</u> Compute the "effective mass" in each mode:

$$M_a = P_a \sum_i M_i \; X_{ia} \tag{5}$$

Thus,

$$[M_a]_{m \times \ell} = [P_a] \times \left[[\phi]^T \; [M] \; [V] \right] \tag{6}$$

where the x on the right side indicates the so-called matrix outer product, in which a term-by-term multiplication is performed. For example, if

$$[C] = [A] \times [B] \tag{7}$$

then

$$c_{ij} = a_{ij} \, b_{ij} \tag{8}$$

<u>Step 4.</u> Compute the "effective weight" $[W_a]$ in each mode by multiplying $[M_a]$ by g, the acceleration due to gravity.

<u>Step 5.</u> Compute the direction-dependent velocity spectrum design values $[V_a]$ from $[W_a]$.

<u>Step 6.</u> Compute the effective static load at each mass, due to the a^{th} mode, by

$$F_{ia} = M_i \, X_{ia} \, P_a \, V_a \, \omega_a \tag{9}$$

where ω_a is the a^{th} natural radian frequency.

The matrix of loads is computed as follows: The matrix product $[M][\phi]$ is of order n x m and corresponds to the product $M_i X_{ia}$ of Equation 9. (Here, only terms of $[M][\phi]$ in the desired directions are used.) The a^{th} column of $[M][\phi]$ corresponds to the a^{th} mode. Multiplying the a^{th} column by ω_a and by $P_a V_a$ for the first desired direction gives a matrix of load vectors of order n x m. If $P_a V_a$'s for other desired directions are used, then other n x m sets of loads are created and appended to the first set. A final load matrix [F], of order n x mℓ, is thus created, where ℓ is the number of desired directions; i.e., there will be mℓ static load cases. (In practice, instead of the product $V_a \omega_a$ in Equation 9, the term actually used is min $(V_a \omega_a, A_a g)$, where A_a is an acceleration spectrum design value in g's and g is the acceleration due to gravity.)

Step 7. Perform static analyses to compute direction-dependent maximum responses, using the load cases from Step 6, and calculate element stresses.

The computation of the effective static load at each mass in Step 6 and the static analyses of Step 7 may be replaced as follows: For the a^{th} mode $\{\phi_a\}$, Equation 9 may be written as

$$\{F_a\} = [M]\{\phi_a\} P_a V_a \omega_a \quad (10)$$

Solving,

$$[K]\{u_a\} = \{F_a\} \quad (11)$$

where [K] is the stiffness matrix and $\{U_a\}$ is the vector of grid point displacements, yields

$$\{u_a\} = [K]^{-1}[M]\{\phi_a\} P_a V_a \omega_a \quad (12)$$

However, from dynamics,

$$[-\omega_a^2 M+K]\{\phi_a\} = 0 \quad (13)$$

or

$$[K]^{-1}[M]\{\phi_a\} = \frac{1}{\omega_a^2}\{\phi_a\} \quad (14)$$

Using Equation 14 in Equation 12 yields

$$\{u_a\} = \{\phi_a\}\frac{P_a V_a}{\omega_a} \quad (15)$$

(As in Step 6, rather than V_a/ω_a, min $(V_a/\omega_a, A_a g/\omega_a)$ is used.)

Equation 15 is used to compute the direction-dependent maximum response.

Step 8. For each of the ℓ desired directions, compute the NRL (Naval Research Laboratory) sums of stresses (see Reference 3) for each element as follows:

$$S_j = \left| S_{jm} \right| + \sqrt{\sum_{b \neq m} (S_{jb})^2} \tag{16}$$

where S_{jm} = maximum stress at the j^{th} point (taken over the modes under consideration in one desired direction) and S_{jb} = stresses (other than the maximum) at the j^{th} point corresponding to the modes described for S_{jm}.

1.16.3 DDAM Implementation in NASTRAN

Since DDAM requires the determination of natural frequencies and mode shapes, a NASTRAN/DDAM analysis involves the use of Rigid Format 3 (Approach DISP) with ALTERs. These ALTERs are required in order to compute the various quantities described in the previous section. Among these ALTERs are instructions for NASTRAN to execute eight functional modules that pertain specifically to DDAM. These modules are briefly described in the following sections.

1.16.3.1 GENCØS

GENCØS generates the direction cosine matrix [V] in Equation 2. The user may specify a coordinate system which defines the shock directions. A PARAM bulk data card giving the value of parameter SHØCK passes to GENCØS the coordinate system identification number of the shock system. If the user does not include such a card, the basic coordinate system will be used. (The value of parameter SHØCK should, in most cases, correspond to the displacement coordinate system identification number for the grid points in the problem. However, to allow for possible exceptions, no check for this correspondence is made.) Parameter DIRECT must also be specified, defining the directions of the shock system which are to be considered. The options for DIRECT are 1, 2, 3, 12, 13, 23 and 123. For example, if DIRECT is 23, then the second and third directions of the shock coordinate system will be used. If the user does not define DIRECT, the default is 123, i.e., all three directions will be considered.

The DMAP statement for GENCØS is

```
GENCØS   BGPDT,CSTM/DIRCØS/C,Y,SHØCK=0/C,Y,DIRECT=123/
                   V,N,LUSET/V,N,NSCALE $
```

1.16.3.2 DDAMAT

DDAMAT calculates a matrix outer product such as that in Equation 6, and multiplies the result by parameter GG. For example, to compute effective weights, Steps 3 and 4 are performed, and GG = g = 386.4 is specified, if units of pounds and inches are used.

The DMAP statement for DDAMAT is

```
DDAMAT   A,B/C/C,Y,GG $
```

Parameter GG must be given a value on a PARAM bulk data card or in the DMAP statement itself.

1.16.3.3 GENPART

It is assumed that, in the eigenvalue analysis, the lowest N modes were computed. If, in the static analyses (or equivalent static analyses), fewer modes are to be used, say, the lowest M, where M < N, then the orders of a number of matrices must be truncated. GENPART generates the partitioning vectors required by functional module PARTN to partition the necessary matrices.

The DMAP statement for GENPART is

```
GENPART   PF/RPLAMB,CPLAMB,RPPF,CPMP/C,Y,LMØDES/V,N,NMØDES $
```

Parameter LMØDES is the integer value of the number of lowest modes to be used in the static analyses. The value of this parameter <u>must</u> be specified on a PARAM bulk data card, or else a fatal error will result.

1.16.3.4 DESVEL

DESVEL computes design velocity and acceleration spectra. The assumed form for velocity is

$$V = V_f V_a \frac{V_b + W}{V_c + W} \tag{17}$$

where V = velocity computed from modified effective weight W,

V_f = factor usually associated with a desired direction,

V_a, V_b, V_c = factors usually associated with various ship types and parameters, and

W = effective weight/1000.

Items V and V_a are in units of length/second, and V_b and V_c are in units of effective weight W.

Acceleration spectrum values may be expressed in one of two forms. The first form is the same as that for velocity

$$A = A_f \, A_a \, \frac{A_b + W}{A_c + W} \tag{18}$$

The second form is

$$A = A_f A_a \, (A_b + W) \, (A_c + W)/(A_d + W)^2 \tag{19}$$

where A = acceleration is in g's for modified effective weight W. A_f, A_a, A_b, A_c and A_d are factors defined similarly to factors V_f, V_a, V_b and V_c. If $A_d = 0$, then the form of Equation 18 is used. In addition, values of $V\omega/g$ are computed and are output along with acceleration values A for comparison purposes. Also, a matrix of minimum values of $V\omega$ and Ag is output for use in Equation 9, i.e.,

$$A_{min} = \min (V\omega, Ag) \tag{20}$$

Finally, the matrix

$$A'_{min} = \frac{1}{\omega^2} \, A_{min} \tag{21}$$

is output for use in Equation 15. Note that the natural frequency must not be zero. However, this is not a restriction for DDAM since a fixed base is assumed.

The DMAP statement for DESVEL is:

```
DESVEL   EFFW,ØMEGA/SSDV,ACC,VWG,MINAC,MINØW2/C,Y,GG = 386.4/
         C,Y,VEL1/C,Y,VEL2/C,Y,VEL3/C,Y,VELA/C,Y,VELB/
         C,Y,VELC/C,Y,ACC1/C,Y,ACC2/C,Y,ACC3/C,Y,ACCA/
                C,Y,ACCB/C,Y,ACCC/C,Y,ACCD $
```

Parameter GG is the acceleration due to gravity. A default value of 386.4 is supplied. Any other value must be specified on a PARAM bulk data card. Parameters VEL1, VEL2 and VEL3 correspond to the factor V_f in Equation 17, in the first, second and third desired directions, respectively. If fewer than three directions are desired, then only VEL1, or VEL1 and VEL2, are specified. For example, if only one direction is specified, say direction 3, than VEL1 corresponds to direction 3, the first (and only) desired direction. Parameters VELA, VELB and VELC correspond to V_a, V_b and V_c, respectively, in Equation 17. These velocity parameters, VEL1 through VELC, <u>must</u> appear

on PARAM bulk data cards, or else a fatal error will result. If VEL2 or VEL3 is not used, then values of 0. must be specified.

Acceleration parameters ACC1 through ACCD are similar to VEL1 through VELC and refer to Equations 18 and 19.

1.16.3.5 DDAMPG

DDAMPG creates the static load vectors of Equation 9 or the maximum responses of Equation 15. For the former, the matrix $[MP] = [M][\phi]$ is input to DDAMPG and is operated on by a matrix

$$[PVW] = [P_a] \times [A_{min}] \tag{22}$$

where $[P_a]$ is the matrix of participation factors defined by Equation 4 and $[A_{min}]$ is computed from Equation 20. The order of these matrices is $m \times \ell$, where m is the number of modes to be used and ℓ is the number of desired directions. [PVW] is formed by functional module DDAMAT.

The columns of [PVW] correspond to desired directions. Within a column, each row term corresponds to a mode. The matrix [MP] is of order $n \times m$, where n is the number of degrees-of-freedom in the problem. Each column of [MP] corresponds to a mode, and in each column of [PVW], the i^{th} row term of [PVW] multiplies the i^{th} column of [MP]. After all columns of [PVW] have been considered, the resulting static load matrix is of order $n \times (m\ell)$.

To compute the maximum response of Equation 15, the same operations just described are performed, except that matrix $[PHIG] = [\phi]$ replaces [MP] and

$$[PV\emptyset W] = \frac{1}{\omega^2} [A_{min}] \tag{23}$$

replaces [PVW], where $\omega = \omega_a$ for the a^{th} row of $[A_{min}]$.

The DMAP statement for DDAMPG for static loads is

```
DDAMPG   MP,PVW/PG/V,N,NMØDES/V,N,NDIR $
```

For maximum responses, the DMAP statement is

```
DDAMPG   PHIG,PVØW/UGV/V,N,NMØDES/V,N,NDIR $
```

1.16.3.6 CASEGEN

The static load and maximum response vectors created in DDAMPG are considered individual load cases by NASTRAN and must, therefore, be selected in the Case Control Deck. The number of cases then is $m\ell$. For example, the use of 30 modes and 3 directions gives a total of 90 cases. Rather than having the user generate the SUBCASE cards, CASEGEN generates a new Case Control Data Table which includes the required cards.

The DMAP statement for CASEGEN is:

```
CASEGEN   CASECC/CASEDD/C,Y,LMØDES/V,N,NDIR/V,N,NMØDES $
```

Parameter LMØDES has the same meaning here as in functional module GENPART and <u>must</u> appear on a PARAM bulk data card, or else a fatal error will result.

1.16.3.7 NRLSUM

Functional module NRLSUM computes the NRL stresses and forces over the m maximum responses for a given direction for each requested element. The NRL sum stress for a given component is

$$S = \left| S_{max} \right| + \sqrt{\sum_{\substack{j \\ j \neq max}} S_j^{\,2}} \tag{24}$$

where S_j is the stress component for the j^{th} mode and S_{max} is the maximum of these stress components taken over all modes under consideration. The Case Control request for stresses and forces are made in the usual way, except that SØRT2 format <u>must</u> be specified. The output device for the NRL sums (printer, punch or both) will be the same as that for the standard stresses and forces. If principal stresses are computed for an element, they will be computed on the basis of the NRL sum of the normal stresses. For the BAR element, the element axial stress in a mode will be added to each of the extensional stresses due to bending in that mode. The NRL sums will then be computed for these new extensional stresses. The NRL sums corresponding to the printed columns headed by AXIAL STRESS, SA-MAX, SB-MAX, SA-MIN, and SB-MIN will be set to 0.

In seismic analyses, the square root of the sums of the squares (SQRSS) is used rather than the NRL sums of the stresses and forces. The user may select the latter method.

The DMAP statement for NRLSUM is

```
NRLSUM   ØES2,ØEF2/NRLSTR,NRLFØR/V,N,NMØDES/V,N,NDIR/C,Y,DIRECT = 123/C,Y,SQRSS = 0 $
```

Parameter DIRECT has the same meaning here as in functional module GENCØS. Integer parameter SQRSS indicates whether the summing process should use NRL sums or the SQRSS method. A value of 0 (the default) indicates NRL sums; a value of 1 indicates SQRSS.

1.16.3.8 CØMBUGV

CØMBUGV combines the direction-dependent maximum response in a number of ways. The method used is intended for DDAM analyses, but seismic analyses, which make use of similar theory, may also be run. In seismic analysis, unlike DDAM, the maximum responses in the three directions for each mode are combined into one total response for the mode. This combination may be performed by simply adding the absolute values of the maximum component responses for the mode, or by computing the square root of the sum of the squares (SQRSS) of the component responses. In both cases, the result is a matrix in which each column represents a total response due to a mode. These responses are then combined by the SQRSS method over the modes to give a final response vector. Finally, the NRL sums of the displacements are also computed.

The DMAP statement for CØMBUGV is

```
CØMBUGV   UGV/UGVADD,UGVSQR,UGVADC,UGVSQC,UGVNRL/V,N,NMØDES/V,N,NDIR $
```

Data block UGVADD is obtained by adding, for each mode, the absolute values of the component responses for that mode. Data block UGVSQR is obtained by using the SQRSS method, rather than by adding. Data blocks UGVADC and UGVSQC are obtained from UGVADD and UGVSQR, respectively, by combining the total modal responses using the SQRSS method. Data block UGVNRL contains the NRL sums of the displacements.

1.16.4 Input Data for DDAM

A complete DDAM analysis with NASTRAN is performed in one normal modes analysis run with a set of DMAP ALTERs. This section describes the input details for such a run.

1.16.4.1 Executive Control Deck

In addition to standard Executive Control Deck cards, the Executive Control Deck for the normal modes analysis must include the proper Rigid Format selection, SØL 3,0 (Approach DISP) and the following DMAP ALTER package. (The numbers to the left of each card are for explanatory purposes only and are not actually entered on the card.)

```
 1. ALTER     n $ (where n = DMAP statement number of LABEL P2)
 2. GENCØS    BGPDT,CSTM/DIRCØS/C,Y,SHØCK =
              0/C,Y,DIRECT = 123/LUSET/S,N,NSCALE $
 3. DIAGØNAL  MI/MID/*SQUARE*/-1. $
 4. MPYAD     MGG, PHIG,/MP/0 $
 5. MPYAD     MP,DIRCØS,/PMD/1 $
 6. MPYAD     MID,PMD,/PF/0 $
 7. DDAMT     PF, PMD/EFFW/C,Y,GG = 386.4 $
 8. LAMX,     ,LAMA/LAMB/-1 $
 9. GENPART   PF/RPLAMB,CPLAMB,RPPF,CPMP/C,Y,LMØDES/S,N,NMØDES $
10. PARTN     LAMB,CPLAMB,RPLAMB/,,,ØMEGA/1 $
11. PARAM     //*GE*/TEST/C,Y,LMØDES/NMØDES $
12. CØND      DDAM, TEST $
13. PARTN     PF,,RPPF/,PFR,,/1 $
14. EQUIV     PFR,PF $
15. PARTN     EFFW,,RPPF/,EFFWR,,/1 $
16. EQUIV     EFFWR,EFFW $
17. PARTN     MP,CPMP,/,,MPR,/1 $
18. EQUIV     MPR,MP $
19. PARTN     PHIG,CPMP,/,,PHIGR,/1 $
20. EQUIV     PHIGR,PHIG $
21. LABEL     DDAM $
22. DESVEL    EFFW,ØMEGA/SSDV,ACC,VWG,MINAC,MINØW2/C,Y,GG=386.4/C,Y,VEL1/
              C,Y,VEL2/C,Y,VEL3/C,Y,VELA/C,Y,VELB/C,Y,VELC/C,Y,ACC1/
              C,Y,ACC2/C,Y,ACC3/C,Y,ACCA/C,Y,ACCB/C,Y,ACCC/C,Y,ACCD $
23. DDAMAT    PF,MINAC/PVW/1. $
24. DDAMAT    PF,MINØW2/PVØW/1.$
25. DDAMPG    PHIG,PVØW/UGV/S,N,NMØDES/S,N,NDIR $
26. DDAMPG    MP,PVW/PG/NMØDES/NDIR $
27. CASEGEN   CASECC/CASEDD/C,Y,LMØDES/NDIR/NMØDES $
28. EQUIV     CASEDD,CASECC $
29. SDR2      CASECC,CSTM,MPT,DIT,EQEXIN,SIL,,,BGPDT,,QG,UGV,EST,,/,ØQG3
              ØUGV3,ØES3,ØEF3,/*STATICS*/S,N,NØSØRT2 = -1/-1 $
30. SDR3      ØUGV3,,ØQG3,ØEF3,ØES3,/ØUGV4,,ØQG4,ØEF4,ØES4, $
31. NRLSUM    ØES4,ØEF4/NRLSTR,NRLFØR/NMØDES/NDIR/C,Y,DIRECT = 123/C,Y,SQRSS = 0 $
32. ØFP       NRLSTR,NRLFØR,,,,//S,N,CARDNØ $
33. CØMBUGV   UGV/UGVADD,UGVSQR,UGVADC,UGVSQC,UGVNRL/NMØDES/NDIR $
34. CASEGEN   CASECC/CASEEE/1/NDIR/NMØDES $
35. SDR2      CASEEE,CSTM,MPT,DIT,EQEXIN,SIL,,,BGPDT,,QG,UGVNRL,EST,,/,,ØUGV5,,,/
              *STATICS*/S,N,NØSØRT2/-1 $
36. ØFP       ØUGV5,,,,,//S,N,CARDNØ $
37. ENDALTER $
```

The following notes on the functional module executions are keyed to the cards with the corresponding numbers.

2. Computes direction cosine matrix [V] in Equation 2.
3. Creates a diagonal matrix, consisting of the diagonal of the modal mass matrix, and inverts it. The new matrix is used in Equation 4.
4. Computes $[M][\phi]$ for later use.
5. Computes $[\phi]^T[M][V]$ as described in Equation 2.
6. Computes matrix of participation factors $[P_a]$ (Equation 4).
7. Computes effective masses and weights in Equation 6.
8. Creates a matrix of the information on the Real Eigenvalue Table for later use in Equation 9.
9. Creates partitioning vectors which will be used to create a vector of natural circular frequencies from a matrix of miscellaneous eigenvalue results. Additionally, if the number of modes to be used in computing maximum responses is less than the number computed in the normal modes analysis, other partitioning vectors are created to reduce the orders of a number of matrices.
10. Creates the vector of natural circular frequencies.
11. Compares the number of desired modes (LMØDES) and the number of computed modes (NMØDES).
12. If LMØDES ≥ NMØDES, skips to 21.

13-20. Reduce orders of several matrices from NMØDES to LMØDES.

22. Computes shock spectrum design velocities and accelerations as given in Equations 17 through 19. In addition, matrices corresponding to Equations 20 and 21 are created for use in Equations 9 and 15, respectively. If Equations 17 through 20 do not represent the desired forms for velocities and accelerations, matrix MINAC or MINØW2 may be directly specified on DMI bulk data cards and functional module DESVEL may be deleted. MINAC and MINØW2 must be of order LMØDES x L; LMØDES is explained in Section 1.16.3.3 above, and L is the number of desired directions.
23. Creates the outer product of Equation 22.
24. Creates the matrix of Equation 23.
25. Computes the LMØDES x L matrix of direction-dependent maximum responses.
26. Creates the LMØDES x L static load matrix as in Equation 9.
27. Generates a new Case Control Data Table which includes the (LMØDES x L) subcases.
29. Computes stresses due to each maximum response.
30. Converts stresses in 29. from SØRT1 to SØRT2.
31. Computes the NRL sum or SQRSS stresses and forces for each requested element.
32. Outputs the NRL sum or SQRSS stresses and forces to the printer and/or punch, as requested in the Case Control Deck.
33. Computes various combinations of the component maximum responses.

34-36. Prepare and print file of NRL sum displacements.

1.16.4.2 Case Control Deck

Although the usual selections may be made, two requirements are imposed:

1. No subcases are to be specified.
2. Stress and force selections must request SØRT2 format.

This last requirement will force all output selections; e.g., displacements, applied loads, etc., to be in SØRT2 format. Also, the NRL sum (or SQRSS) stresses and forces will be printed and/or punched, as requested in the corresponding STRESS and FØRCE requests.

1.16.4.3 Bulk Data Deck

The values of a number of parameters special to DDAM must be specified. For those parameters with no default values and for parameters for which the default values are to be overridden, PARAM bulk data cards will be required. The parameters are as follows:

1. SHØCK - The nonnegative integer value of this parameter is the identification number of the coordinate system which defines the shock direction. A non-zero value requires definition of the system on a CØRDij card. A zero value implies the basic coordinate system with shock directions X, Y and Z. The default value is zero. The value of SHØCK should, in most cases, be the same as the displacement coordinate system identification number for the grid points.
2. DIRECT - This parameter may have one of the following integer values: 1, 2, 3, 12, 13, 23 or 123. The default value is 123. The value of DIRECT indicates which directions of coordinate system SHØCK are to be considered. For example, if DIRECT = 123, then all three directions will be used. If DIRECT = 13, only two directions will be used, the first and the third.
3. GG - The real value of this parameter is the acceleration due to gravity. The default value is 386.4.
4. LMØDES - The integer value of this parameter is the number of lowest modes to be used in the static analyses. This number may be less than the number of modes computed in the normal modes analysis. No default value is provided so the value of this parameter must be given on a PARAM bulk card or else a fatal message will result.
5. VEL1,VEL2,VEL3,VELA,VELB,VELC,ACC1,ACC2,ACC3,ACCA,ACCB,ACCC,ACCD - The real values of these parameters control the computation of the shock spectrum design values for velocity and acceleration. These parameters are defined by Equations 17 through 19 and further

explained in Section 1.16.3.4. No default values for any of these parameters are provided, so a PARAM bulk data card for each parameter must be included in the Bulk Data Deck.

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1.17 PIEZOELECTRIC MODELING

1.17.1 Introduction

The analysis of sonar transducers requires accounting for the effects of their piezoelectric materials. The theory for these materials couples structural displacements to electric potentials. This theory has been incorporated into the finite element formulations of the TRAPAX and TRIAAX elements in NASTRAN. (See Reference 1 for details of the implementation.) These elements, trapezoidal and triangular in cross-section respectively, are solid, axisymmetric rings whose degrees-of-freedom are expanded into Fourier series, thus allowing nonaxisymmetric loads.

1.17.2 Theory

The constitutive relations of a piezoelectric material may be written as

$$\begin{Bmatrix} \{\sigma\} \\ \\ \{D\} \end{Bmatrix} = \begin{bmatrix} [c^E] & [e] \\ \\ [e]^T & -[\varepsilon^S] \end{bmatrix} \begin{Bmatrix} \{\varepsilon\} \\ \\ \{E\} \end{Bmatrix} \tag{1}$$

where $\{\sigma\}$ = stress components = $\lfloor \sigma_{rr}, \sigma_{zz}, \sigma_{\theta\theta}, \sigma_{rz}, \sigma_{r\theta}, \sigma_{z\theta} \rfloor^T$

$\{D\}$ = components of electric flux density = $\lfloor D_{rr}, D_{zz}, D_{\theta\theta} \rfloor^T$

$\{\varepsilon\}$ = mechanical strain components,

$\{E\}$ = electric field components,

$[c^E]$ = elastic stiffness tensor evaluated at constant electric field,

$[e]$ = piezoelectric tensor, and

$[\varepsilon^S]$ = dielectric tensor evaluated at constant mechanical strain.

The displacement vector of a point within an element is taken to be

$$\{\bar{u}\} = \begin{Bmatrix} u \\ v \\ w \\ \phi \end{Bmatrix} \tag{2}$$

where u, v and w are the ring displacements in the radial, tangential, and axial directions,

respectively, and ϕ is the electric potential. The latter degree-of-freedom is taken to be the fourth degree-of-freedom at each ring. Each of these quantities is expanded into a Fourier series with respect to the aximuth position Θ. The Fourier series for the electric potential ϕ has the same form as the Fourier series for radial displacement u, as given in Section 5.11.1 of the Theoretical Manual.

The "stiffness" matrix for the Nth harmonic is

$$[K^{(N)}] = \pi \iint_{r\,z} [B^{(N)}]^T \begin{bmatrix} [c^E] & [e] \\ [e]^T & -[\varepsilon^S] \end{bmatrix} [B^{(N)}] \, rdrdz \tag{3}$$

where $[B^{(N)}]$ is the matrix of "strain"-"displacement" coefficients for the Nth harmonic.

Equations 2 and 3 indicate that the matrix equation to be solved for static analysis may be partitioned as follows:

$$\begin{bmatrix} [K_{\delta\delta}] & [K_{\delta\phi}] \\ [K_{\phi\delta}] & [K_{\phi\phi}] \end{bmatrix} \begin{Bmatrix} \{\delta\} \\ \{\phi\} \end{Bmatrix} = \begin{Bmatrix} \{F_\delta\} \\ \{F_\phi\} \end{Bmatrix} \tag{4}$$

where
$\{\delta\} = \lfloor u_1, v_1, w_1, \ldots, u_n, v_n, w_n \rfloor^T$
$\{d\} = \lfloor \phi_1, \ldots, \phi_n \rfloor^T$
$\{F_\delta\}$ = vector of structural forces, and
$\{F_\phi\}$ = vector of electrical charges.

Note, however, that the program assumes that the electric potential ϕ_i is the fourth degree-of-freedom of grid point i.

Both lumped and consistent mass matrices are available and are of standard structural form; i.e., the mass matrix does not couple the structural and electrical unknowns. The structural damping matrix also is of standard structural form. Both point charges and surface charges are also available.

1.17.3 Input Data for Piezoelectric Modeling

Piezoelectric modeling requires some special input data. These include the specification of a

parameter on the NASTRAN card as well as the use of one or more of four bulk data cards that pertain specifically to piezoelectric modeling. In addition, some other bulk data cards are treated differently when used in piezoelectric modeling. The details are discussed in the following sections.

1.17.3.1 NASTRAN Card

The NASTRAN card allows the user to override various NASTRAN system parameters by defining specific words in the /SYSTEM/ CØMMØN block (see Section 2.1). The 78th word of /SYSTEM/, that is, SYSTEM (78), has been set aside to indicate the use of piezoelectric materials. The default value for SYSTEM(78) is zero, implying that no piezoelectric materials are allowed. If SYSTEM(78) = 1, piezoelectric materials are allowed and coupling occurs between the structural and electric degrees-of-freedom. If SYSTEM(78) = 2, piezoelectric materials are allowed, but no coupling occurs and electrical effects are not taken into account.

Setting SYSTEM(78) to its proper value is important for several reasons:

1. If SYSTEM(78) = 0, no piezoelectric materials are expected, and MATPZ1 and MATPZ2 cards (see Section 1.17.3.2) will not be searched.
2. If SYSTEM(78) ≠ 1, a negative ring identification number is not allowed on the PRESAX card (see Section 1.17.3.2).
3. If SYSTEM(78) ≠ 1, NASTRAN will automatically constrain degree-of-freedom 4 (the electric potential) at each ring for the zero harmonic in the AXISYMMETRIC = CØSINE case.
4. If SYSTEM(78) = 2, some time will be saved in generating the "stiffness" matrix compared to the time for the SYSTEM(78) = 1 case.
5. If SYSTEM(78) ≠ 1, degrees-of-freedom 4, 5 and 6 must be removed from the problem via SPCAX or RINGAX cards. If SYSTEM(78) = 1, only degrees-of-freedom 5 and 6 must be removed.

1.17.3.2 Bulk Data Deck

There are four bulk data cards that pertain specifically to piezoelectric modeling. All these cards define piezoelectric material properties. These properties are usually described by the following matrices:

$$[s^E] = \begin{bmatrix} s_{11}^E & s_{12}^E & s_{13}^E & 0 & 0 & 0 \\ s_{12}^E & s_{11}^E & s_{13}^E & 0 & 0 & 0 \\ s_{13}^E & s_{13}^E & s_{33}^E & 0 & 0 & 0 \\ 0 & 0 & 0 & s_{44}^E & 0 & 0 \\ 0 & 0 & 0 & & s_{44}^E & 0 \\ 0 & 0 & 0 & 0 & 0 & s_{66}^E \end{bmatrix} \tag{5}$$

where $s_{66}^E = 2(s_{11}^E - s_{12}^E)$

$$[d] = \begin{bmatrix} 0 & 0 & 0 & 0 & d_{15} & 0 \\ 0 & 0 & 0 & d_{15} & 0 & 0 \\ d_{31} & d_{31} & d_{33} & 0 & 0 & 0 \end{bmatrix} \tag{6}$$

$$[\varepsilon^S] = \begin{bmatrix} \varepsilon_{11}^S & 0 & 0 \\ 0 & \varepsilon_{11}^S & 0 \\ 0 & 0 & \varepsilon_{33}^S \end{bmatrix} \tag{7}$$

The matrices in Equation 1 are computed as follows:

$$[c^E] = [s^E]^{-1} \tag{8}$$

$$[e] = [d][c^E] \tag{9}$$

and $[\varepsilon^S]$ is given by Equation 7.

Two of the bulk data cards, MATPZ1 and MATPZ2, describe the piezoelectric material properties in two different ways. MATPZ1 is used to specify the parameters in Equations 5 through 7. MATPZ2 is more general and allows the user to enter the full matrices $[c^E]$, $[e]$ and $[\varepsilon^S]$. The only

assumption concerning these matrices is that $[c^E]$ and $[\varepsilon^S]$ are symmetric. CAUTION: Piezoelectric electric material properties are usually specified with respect to a standard set of material axes 1, 2, 3. For axisymmetric solids, direction 1 coincides with the Z-axis and direction 2 coincides with the θ-axis. Polarization direction 3 may vary in the R-Z plane and, for radial polarization, coincides with the R-axis. When a user specifies properties on a MATPZ1 card, the transformation from the 1, 2, 3 directions to the R, Z, θ directions is performed by NASTRAN. However, such a transformation is not performed by NASTRAN when the MATPZ2 card is used. Also, the ordering of the components of the stress and strain vectors is somewhat different for conventional piezoelectric specifications and for NASTRAN. The difference is that the ordering of the Z-θ and R-Z shears is interchanged. Once again, NASTRAN performs the transformation for MATPZ1, but not for MATPZ2.

The other two data cards, MTTPZ1 and MTTPZ2, allow the values on the MATPZ1 and MATPZ2 cards to be temperature-dependent. (However, the TRAPAX and TRIAAX elements have not yet been modified to handle the combination of thermal laods and piezoelectric materials.)

Point and surface charges may be specified in piezoelectric modeling. These charges are analogous to structural point loads and pressures, respectively, and are entered into $\{F_\phi\}$ in Equation 4. Since the electric potential is associated with degree-of-freedom 4, point charges may be applied to specific harmonics with MØMAX bulk data cards or may be specified by MØMENT, MØMENT1, or MØMENT2 cards applied to PØINTAX points. In the latter case, the direction of the "moment" must be about the radial direction, i.e., degree-of-freedom 4. The MKS unit of the point charge is coulombs.

The PRESAX bulk data card is used to specify surface charges. However, in order to distinguish between surface charges and structural pressure loads within the same problem, the first-specified ring identification number on the PRESAX card (field 4) must be made negative if a surface charge is desired. A negative ring identification number is, however, allowed only when the parameter SYSTEM(78) is set to 1 on the NASTRAN card.

1.17.4 Notes on Piezoelectric Modeling

The following notes summarize the important points about piezoelectric modeling and should prove helpful to the user.

1. In order to use piezoelectric materials, SYSTEM(78) must be set to 1 or 2 on the NASTRAN card. (The default value is 0.) A value of 1 indicates electrical-structural coupling

and a value of 2 allows the use of piezoelectric materials, but does not take into account any electrical effects. The latter case requires that the degrees-of-freedom corresponding to the electric potential be constrained.

2. The electric potential at each ring is considered to be degree-of-freedom 4. Degrees-of-freedom 5 and 6 always have zero stiffness and must be removed from the problem with SPCAX or RINGAX cards. (Degree-of-freedom 4 must also be removed if SYSTEM(78) = 2.) Electroded surfaces (surfaces of constant potential) may be specified with MPCAX cards.

3. Only TRAPAX and TRIAAX elements may reference piezoelectric material cards MATPZ1 and MATPZ2.

4. Standard material cards MAT1 and MAT3 are allowed in problems which also contain piezoelectric materials.

5. The S^E and d values on MATPZ1 cards will be multiplied by 10^{-12} by NASTRAN. Also, the value of ε_0 is fixed in NASTRAN as 8.854×10^{-12} farad/meter.

6. As may be seen from Equation 3, the lower right-hand portion of the stiffness matrix is negative-definite. This situation does not affect NASTRAN execution except that grid point singularity warning messages are issued for all unconstrained electric potentials.

7. To specify surface charge loads, the first ring identification number on the PRESAX card (field 4) must be negative. This format change will allow NASTRAN to distinguish between electrical charges and structural pressures within a piezoelectric run. However, this change is allowed only when SYSTEM(78) = 1.

8. Lumped mass and consistent mass are available for TRAPAX and TRIAAX elements. The mass associated with the electric potential degree-of-freedom is zero. Therefore, if a normal modes analysis by GIVENS method is run, all unconstrained electric potentials must appear on ØMIT cards.

9. If a structural damping coefficient is specified on a MATPZ1 or MATPZ2 card in a dynamics problem, the terms of the resulting structural damping matrix corresponding to electric potentials will be zero. The uniform structural damping parameter G in direct frequency response problems should not be used, since its use will result in structural damping terms corresponding to the electric potentials.

10. Earlier versions of NASTRAN could not handle stresses or forces, whether real or complex, in axisymmetric (AXIC) dynamics problems. However, NASTRAN can now handle all such cases for the TRAPAX and TRIAAX finite elements.

11. Material properties specified on MATPZ1 cards are transformed by NASTRAN from the standard 1, 2, 3 material directions to the R, Z, Θ directions. Also, the transformation required due to a switch in the order of the R-Z and Z-Θ shears between conventional specifications and NASTRAN is performed for MATPZ1 properties. However, material properties on MATPZ2 cards are used by NASTRAN as they appear on the card. Therefore, any required transformation must be performed by the user.

REFERENCE

1. Lipman, R. R., and Hurwitz, M. M., "Piezoelectric Finite Elements for NASTRAN," David W. Taylor Naval Ship Research and Development Center, Report Number DTNSRDC-80/045, April 1980.

2. NASTRAN DATA DECK

2.0 GENERAL DESCRIPTION OF DATA DECK

The input deck begins with the required resident operating system control cards. The type and number of these cards will vary with the installation. Instructions for the preparation of these control cards should be obtained from the programming staff at each installation.

The operating system control cards are followed by the NASTRAN Data Deck (see Figure 1), which is constructed in the following order (depending on the particular job requirements):

1. The NASTRAN Card (optional)
2. The Executive Control Deck (required)
3. The Substructure Control Deck (required only in substructure analyses)
4. The Case Control Deck (required)
5. The Bulk Data Deck (required)
6. The INPUT Module Data Card(s) (required only if the INPUT module is used)

The NASTRAN card is used to change the default values for certain operational parameters, such as the buffer size and the machine configuration. The NASTRAN card is optional, but, if present, it must be the first card of the NASTRAN Data Deck. It is described in detail in Section 2.1.

The Executive Control Deck begins with the NASTRAN ID card and ends with the CEND card. It identifies the job and the type of solution to be performed. It also declares the general conditions under which the job is to be executed, such as, maximum time allowed, type of system diagnostics desired, restart conditions, and whether or not the job is to be checkpointed. If the job is to be executed with a rigid format, the number of the rigid format is declared along with any alterations to the rigid format that may be desired. If Direct Matrix Abstraction is used, the complete DMAP sequence must appear in the Executive Control Deck. The executive control cards and examples of their use are described in Section 2.2.

The Substructure Control Deck begins with the SUBSTRUCTURE card and terminates with the ENDSUBS card. It defines the general attributes of the Automated Multi-stage Substructuring capability and establishes the control of the Substructure Operating File (SØF). The command cards are described in Section 2.7.

When Automated Multi-stage Substructuring is not included, then the Case Control Deck begins with the first card following CEND and ends with the BEGIN BULK card. It defines the subcase structure for the problem, makes selections from the Bulk Data Deck, and makes output requests for printing, punching and plotting. A general discussion of the functions of the Case Control Deck

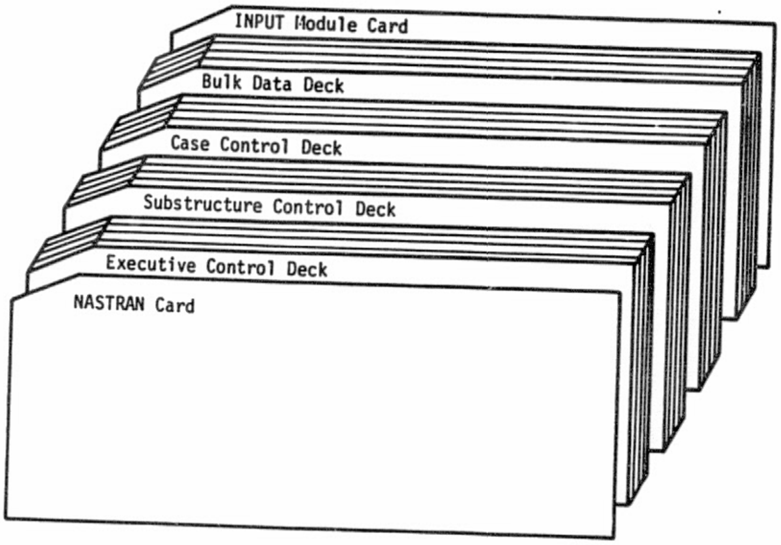

Figure 1. General construction of NASTRAN data deck.

and a detailed description of the cards used in this deck are given in Section 2.3. The special requirements of the Case Control Deck for each rigid format are discussed in Section 3.

The Bulk Data Deck begins with the card following BEGIN BULK and ends with the card preceding ENDDATA. It contains all of the details of the structural model and the conditions for the solution. A detailed description of all of the bulk data cards is given in Section 2.4. The BEGIN BULK and ENDDATA cards must be present even though no new bulk data is being introduced into the problem or all of the bulk data is coming from an alternate source, such as User's Master File or user generated input. The format of the BEGIN BULK card is free field. The ENDDATA card must begin in column 1 or 2. Generally speaking, only one structural model can be defined in the Bulk Data Deck. However, some of the bulk data, such as cards associated with loading conditions, constraints, direct input matrices, transfer functions and thermal fields may exist in multiple sets. All types of data that are available in multiple sets are discussed in Section 2.3.1. Only sets selected in the Case Control Deck will be used in any particular solution.

If the INPUT module is employed, one or two additional data cards are required <u>following</u> the ENDDATA card. For specific cases, see Section 2.6.

Comment cards may be inserted in any of the parts of the NASTRAN Data Deck. These cards are identified by a $ in column one. Columns 2-72 may contain any desired text.

2.1 THE NASTRAN CARD

Many of the important operational parameters used in NASTRAN, such as the buffer size and the machine configuration, are contained in the /SYSTEM/ CØMMØN block. These and other operational parameters are initially assigned values by the program. However, the program does provide a means by which the default values initially set for some of these operational parameters can be redefined by the user at execution time. The card that provides this capability is called the NASTRAN card.

The NASTRAN card is optional, but, if used, it must be the <u>first</u> card of the NASTRAN data deck, that is, it must <u>precede</u> the Executive Control Deck. The NASTRAN card is a free-field card (similar to the cards in the Executive and Case Control Decks). The format of the card is as follows:

NASTRAN keyword_1 = value, keyword_2 = value, ...

The list of applicable and acceptable keywords is as follows:

1. BANDIT - Changes the 77th word in /SYSTEM/. This parameter specifies whether the BANDIT operations in NASTRAN are to be performed or not. If BANDIT = 0 (the default), the BANDIT operations are performed if there are no input data errors. If BANDIT = -1, the BANDIT operations are skipped unconditionally.

2. BANDTCRI - Manipulates the 77th word in /SYSTEM/. This parameter specifies the criterion for evaluation in the BANDIT operations. Acceptable values and their meanings are shown below. (See Reference 1 for the definitions of the terms used here.)

BANDTCRI value	Criterion for evaluation (characteristic of matrix selected for reduction)
1 (default)	RMS (root mean square) wavefront
2	Bandwidth
3	Profile
4	Maximum wavefront

3. BANDTDEP - Manipulates the 77th word in /SYSTEM/. This parameter is meaningful only when the BANDTMPC parameter is set to 1 or 2. It indicates whether the dependent grid points specified by multipoint constraints (MPCs) and/or rigid elements are to be included (BANDTDEP=0, the default) or are to be excluded (BANDTDEP=1) from consideration in the BANDIT computations.

4. BANDTDIM - Manipulates the 77th word in /SYSTEM/. This parameter defines the dimension (in number of words) of a scratch array used in the BANDIT computations. Any one of the integers 1 to 9 may be specified, resulting in a dimension of 100 x m words for the scratch array (m = the value specified for this parameter). If this parameter is not specified, a value of 150 words is used as the default dimension for the scratch array.

5. BANDTMPC - Manipulates the 77th word in /SYSTEM/. This parameter indicates whether

multipoint constraints (MPCs) and/or rigid elements are to be considered in the BANDIT computations. Acceptable values and their meanings are shown below.

BANDTMPC value	Meaning
0 (default)	Do not consider MPCs or rigid elements in the BANDIT computations.
1	Consider only rigid elements in the BANDIT computations.
2	Consider both MPCs and rigid elements in the BANDIT computations.

As noted in Reference 1, it should emphasized be here that only in rare cases would it make sense to let BANDIT process MPCs and rigid elements. The main reasons for this are that the BANDIT computations do not consider individual degrees of freedom and, in addition, cannot distinguish one MPC set from another.

6. BANDTMTH - Manipulates the 77th word in /SYSTEM/. This parameter specifies the method to be used by the BANDIT operations for the resequencing of grid points. (See Reference 1 for details of these methods.) Acceptable values and their meanings are shown below.

BANDTMTH value	Method(s) to be used in the BANDIT operations
1	Cuthill-McKee method
2 (default)	Cuthill-McKee method and Gibbs-Poole-Stockmeyer method
3	Gibbs-Poole-Stockmeyer method

7. BANDTPCH - Manipulates the 77th word in /SYSTEM/. This parameter specifies the punching of the SEQGP cards generated by the BANDIT procedure. Acceptable values and their meanings are given below.

BANDTPCH value	Meaning
0 (default)	Do not punch the SEQGP cards generated by BANDIT and let the NASTRAN job continue normally.
1	Punch out the SEQGP cards generated by BANDIT and terminate the NASTRAN job.

8. BANDTRUN - Manipulates the 77th word in /SYSTEM/. This parameter specifies the conditions under which the BANDIT operations in NASTRAN are to be performed. A value of 0 (the default) indicates that the BANDIT computations are to be performed if there are no input data errors and the user has not already included one or more SEQGP cards in the Bulk Data Deck. A value of 1 specifies that the BANDIT operations are to be performed if there are no input data errors and new SEQGP cards are to be generated unconditionally to replace any old SEQGP cards that may have been initially included in the user input.

9. BUFFSIZE - Changes the first word in /SYSTEM/. This word defines the number of words in a GINØ (general purpose input/output routines used in NASTRAN) buffer. The default values are as follows:

Machine	GINØ Buffer Size (words)
CDC	1042
IBM	1826
UNIVAC	1795
DEC VAX	1408

The desired value at a particular installation may be different from the default value. In any event, related runs such as restarts and User's Master File (UMF) runs must use the same BUFFSIZE for all parts of the run.

10. BULKDATA - Changes the 77^{th} word in /SYSTEM/. This parameter specifies whether NASTRAN is to run normally (BULKDATA=0, the default) or if NASTRAN is to terminate after the Preface (or Link 1) operations (BULKDATA≠0).

Important note about the BANDIT, BANDTxxx and BULKDATA Parameters

Note that the BANDIT parameter, the BANDTxxx parameters (as a group) and the BULKDATA parameter all correspond to the same word (the 77^{th} word) in the /SYSTEM/ CØMMØN block. Hence, these parameters are mutually exclusive. That is, the user can specify either the BANDIT parameter, any one or more of the BANDTxxx parameters or the BULKDATA parameter, but he cannot specify more than one of these three parameters.

11. CØNFIG - Changes the 28^{th} word in /SYSTEM/. For a given machine type (which is automatically determined by NASTRAN), this word defines the model number of the configuration for use in the timing equations for matrix operations. Currently, entries exist for the following configurations:

Machine	CØNFIG	Model No.
CDC 6000 (no default; see discussion below)	6	6400/6500
	16	6600
CDC CYBER 170 (no default; see discussion below)	0	175
	12	174
	14	173
	15	176
IBM 360	0 (default)	91,95
	4	65
	5	75
	6	85
	7	195
IBM 370 (no default)	3	3033
	9	155
	10	165
	11	148
	12	158
	13	168
UNIVAC 1100	0 (default)	1110
	14	1108
DEC VAX	0 (default)	11/780

It is important to indicate the proper configuration on the NASTRAN card; otherwise, all time-dependent matrix decisions will be incorrect. If the model number is the default, the CØNFIG keyword is not needed on the NASTRAN card. (On the CDC version, if the CØNFIG keyword is not specified on the NASTRAN card, the model number is automatically determined by NASTRAN by means of certain timing tests.)

12. DRUM - Changes the 34^{th} word in /SYSTEM/. This word defines the drum allocation of dynamic assigns on the UNIVAC version. The default is DRUM = 1. This causes dynamic

assigns for all units not assigned by the user to be of the following form:

@ASG,T XX,F17//PØS/30.

This assign card allows a maximum of 1,920 tracks, or approximately 3,500,000 words for each file. The F17 refers to a mass storage device. PØS requests that 64 contiguous tracks be assigned at once. The value 30 causes the run to be terminated if more than 30 x 64 tracks of data are written on any one file.

The drum allocation of dynamic assigns can be changed from PØS (positions) to TRK (tracks) by setting DRUM = 2. This results in files being assigned in the following form:

@ASG,T XX,F17//TRK/1920.

TRK requests that 64 sectors (28 words/sector) be assigned at one time.

13. FILES - Establishes the specified NASTRAN files as executive files. The files that may be specified are PØØL, NPTP, ØPTP, UMF, NUMF, PLT2, INPT, INP1, INP2,....,INP9. Multiple file names must be specified by enclosing them in parantheses, such as FILES = (UMF, NPTP). If an executive file is assigned to tape rather than disk, then it need not be specified with the FILES parameter. The FILES parameter, if used, must be the last keyword on the NASTRAN card.

14. HICØRE - Changes the 31st word in /SYSTEM/. This word defines the amount of core (in decimal words) available to the user on the UNIVAC 1100 series machines. The default is 65K decimal words. The ability to increase this value may be installation limited.

15. MAXFILES - Changes the 29th word in /SYSTEM/. This word defines the maximum number of files to be placed in CØMMØN /XFIAT/ by subroutine GNFIAT. The default value is 35.

16. MAXØPEN - Changes the 30th word in /SYSTEM/. This word defines the maximum number of files that may be open at any one time in the program. The default value is 16.

17. MØDCØM(I) - Changes the (56 + I)th word ($1 \le I \le 9$) in /SYSTEM/. Defines one of the words in a nine-word array. Currently, only MØDCØM(1) is supported. If MØDCØM(1) = 1, diagnostic statistics from subroutine SDCØMP are printed. The default is MØDCØM(1) = 0, resulting in no diagnostic prints from SDCØMP.

18. NLINES - Changes the 9th word in /SYSTEM/. This word defines the number of data lines per printed page. The smallest acceptable value is 10. The default value is 42 for the CDC and IBM versions, 50 for the DEC VAX version and 55 for the UNIVAC version. Alternatively, the number of data lines per printed page can also be defined by means of the LINE card in the Case Control Deck (see Section 2.3).

19. STST - Changes the 70th word in /SYSTEM/. This word defines the singularity tolerance for use in the EMA module. The default value is 0.01. The singularities remaining are written onto the GPST data block output from EMA.

20. SYSTEM(J) - Changes the Jth word ($1 \le J \le 100$) in /SYSTEM/. This is the general form of defining any word in /SYSTEM/. Note, for instance, that BUFFSIZE and SYSTEM(1) are equivalent and CØNFIG and SYSTEM(28) are equivalent. The contents of /SYSTEM/ are described fully in Section 2.4.1.8 of the Programmer's Manual.

21. TITLEØPT - Defines the option for obtaining the title page in the NASTRAN output. The values of this keyword and their meaning are as follows:

TITLEØPT	Meaning
<0	Print a short title page.
0	Do not print any title page.
1	Print one copy of the full title page.

2 (default)	Print two copies of the full title page.
3	Print a one-line comment (which can be modified by the user by updating subroutine TTLPGE) followed by the short title items on the same page.
4	Read another card immediately following the NASTRAN card, print its contents on one line and follow it by the short title items on the same page.
>4	Do not print any title page (same as TITLEØPT = 0).

As can be seen, when TITLEØPT = 4 is specified on the NASTRAN card, the user must supply another card immediately following the NASTRAN card to be read by the program. The user can therefore utilize this feature to print one-line individual comments (along with the short title) for individual runs.

Examples

Following are some examples of the use of the NASTRAN card.

Example 1

NASTRAN BUFFSIZE = 900, SYSTEM(2) = 3, CØNFIG = 3

The above card changes the 1st, 2nd and 28th words of /SYSTEM/. SYSTEM(2) = 3 changes the system output unit from 6 (default) to 3.

Example 2

NASTRAN SYSTEM(4) = 4, NLINES = 40

The above card changes the 4th and and 9th words of /SYSTEM/. SYSTEM(4) = 4 changes the system input unit from 5 (default) to 4. This means that all subsequent input data must be present on unit 4.

Example 3

NASTRAN TITLEØPT = -1, FILES = (UMF, NPTP)

The above card requests a short title page and establishes the UMF and NPTP files as executive files.

Example 4

NASTRAN SYSTEM(14) = 30000, SYSTEM(79) = 16384

The above card changes the 14th and 79th words in /SYSTEM/. SYSTEM(14) = 30000 changes the maximum number of output lines from 20000 (default) to 30000. (See the description of the MAXLINES card in Section 2.3.) SYSTEM(79) = 16384 turns on DIAG 15 thereby requesting the tracing of GINØ ØPEN/CLØSE operations. (See the description of the DIAG card in Section 2.2.)

Example 5

NASTRAN BANDTPCH = 1, BANDTRUN = 1

The above card requests the punching of the new SEQGP cards unconditionally generated by the BANDIT procedure and the subsequent termination of the NASTRAN job.

Example 6

NASTRAN BANDIT = -1

The above card requests the unconditional skipping of the BANDIT operations.

REFERENCE

1. Everstine, G. C., BANDIT User's Guide, COSMIC Program No. DOD-00033, May 1978.

2.2 EXECUTIVE CONTROL DECK

2.2.1 Control Selection

The format of the Executive control cards is free field. The name of the operation (e.g., CHKPNT) is separated from the operand by one or more blanks. The fields in the operand are separated by commas, and may be up to 8 integers or alphanumeric as indicated in the control card descriptions. The first character of an alphanumeric field must be alphabetic followed by up to 7 additional alphanumeric characters. Blank characters may be placed adjacent to separating commas if desired. The individual cards are described in Section 2.3.3 and examples follow in Section 2.2.2.

The following Executive Control cards are mandatory:

1. APP - selects a Rigid Format approach or a user provided Direct Matrix Abstraction Program (DMAP).
2. CEND - defines the end of the Executive Control deck.
3. ID - defines the beginning of the Executive Control deck.
4. TIME - defines the maximum time in minutes allotted to the execution of the NASTRAN program.

The following Executive Control cards are required under certain circumstances:

1. BEGIN$ - defines the beginning of user provided DMAP statements.
2. END$ - defines the end of user provided DMAP statements.
3. ENDALTER - defines the end of user provided changes to a Rigid Format.
4. RESTART - defines the beginning of a restart dictionary.
5. SØL - selects the solution number of a Rigid Format.
6. UMF - selects a data deck from a User Master File.
7. UMFEDIT - controls execution as a UMF editor.

The following Executive Control cards are optional:

1. ALTER - defines the Rigid Format statement(s) at which the user makes alterations.
2. CHKPNT - requests the execution to be checkpointed.
3. DIAG - requests diagnostic output to be provided or operations to be effected.
4. NUMF - requests a User Master File to be created.
5. $ - defines a non-executable comment.

2.2.2 Executive Control Deck Examples

1. Cold start, no checkpoint, rigid format, diagnostic output.

```
ID          MYNAME, BRIDGE23
APP         DISPLACEMENT
SØL         2,0
TIME        5
DIAG        1,2
CEND
```

2. Cold start, checkpoint, rigid format.

```
ID          PERSØNZZ, SPACECFT
CHKPNT      YES
APP         DISPLACEMENT
SØL         1,3
TIME        15
CEND
```

3. Restart, no checkpoint, rigid format. The restart di ionary indicated by the brace is automatically punched on previous run in which the CHKPNT option was selected by the user.

```
ID JØESHMØE, PRØJECTX
RESTART  PERSØNZZ, SPACECFT, 05/13/67, 18936,
     1, XVPS, FLAGS=0, REEL=1, FILE=6
     2, REENTER AT DMAP SEQUENCE NUMBER 7
     3, GPL, FLAGS=0, REEL=1, FILE=7
                  .
                  .
                  .
$ END ØF CHECKPØINT DICTIØNARY
APP         DISPLACEMENT
SØL         3,3
TIME        10
CEND
```

4. Cold start, no checkpoint, DMAP. User-written DMAP program is indicated by braces.

```
ID          IAM007, TRYIT
APP         DMAP
BEGIN $
{DMAP statements go here}
END $
TIME        8
CEND
```

5. Restart, checkpoint, altered rigid format, diagnostic output.

```
ID BEAM, FIXED
RESTART BEAM, FREE, 05/09/68, 77400,
     1, XVPS, FLAGS=0, REEL=1, FILE=6
     2, REENTER AT DMAP SEQUENCE NUMBER 7
     3, GPL, FLAGS=0, REEL=1, FILE=7
                  .
                  .
                  .
$ END ØF CHECKPØINT DICTIØNARY
```

```
CHKPNT     YES
DIAG       2,4
APP        DISPLACEMENT
SØL        3,3
TIME       15
ALTER      20 $
MATPRN     KGGX,,,,// $
TABPT      GPST,,,,// $
ENDALTER
CEND
```

2.2.3 Executive Control Card Descriptions

The format of the Executive Control cards is free-field. In presenting general formats for each card embodying all options, the following conventions are used:

1. Upper-case letters and parentheses must be punched as shown.
2. Lower-case letters indicate that a substitution must be made.
3. Braces { } indicate that a choice of contents is mandatory.
4. Brackets [ ] contain an option that may be omitted or included by the user.
5. Underlined options or values are the default values.
6. Physical card consists of information punched in columns 1 thru 72 of a card. Most Executive Control cards are limited to a single physical card.
7. Logical card may have more than 72 columns with the use of continuation cards. A continuation card is honored by ending the preceeding card with a comma.

Executive Control Card ALTER - DMAP Sequence Alteration Request

Description: Requests Direct Matrix Abstraction Program (DMAP) sequence for a Rigid Format to be changed by additions, deletions, or substitutions.

Format and Example(s):

ALTER {K1 [,K2]} $

ALTER 22 $

ALTER 5,5 $

ALTER 38,45 $

Option	Meaning
K1 and K2	First and last DMAP instruction statement numbers of series to be deleted and replaced with any following DMAP instructions.
K1 only	Input following DMAP instructions after statement number K1.

Remarks:

1. ALTER statement numbers must be in increasing order.
2. For a list of the Rigid Format DMAP sequences, see Section 3.
3. See Section 3.1.5 for the manner in which ALTERs are handled in restarts.

Executive Control Card APP - Rigid Format or DMAP Declaration

Description: Selects a Rigid Format approach or a user provided Direct Matrix Abstraction Program (DMAP).

Format and Example(s):

```
     ⎧ DISPLACEMENT       ⎫
     ⎪ DISPLACEMENT, SUBS ⎪
APP  ⎨ HEAT               ⎬
     ⎪ AERØ               ⎪
     ⎪ DMAP               ⎪
     ⎩ DMAP, SUBS         ⎭
```

APP HEAT

APP DMAP

Option	Meaning
DISPLACEMENT	Indicates one of the Displacement Approach rigid formats.
DISPLACEMENT, SUBS	Indicates Automated Multi-stage Substructuring with one of the Displacement Approach rigid formats.
HEAT	Indicates one of the Heat Transfer Approach rigid formats.
AERØ	Indicates one of the Aeroelastic Approach rigid formats.
DMAP	Indicates Direct Matrix Abstraction Program (DMAP) Approach.
DMAP, SUBS	Indicates Direct Matrix Abstraction Program (DMAP) Approach which includes Automated Multi-stage Substructuring modules.

Remarks: 1. This card is mandatory.

Executive Control Card BEGIN - DMAP Sequence Initiation

Description: Defines the beginning of a Direct Matrix Abstraction Program (DMAP) sequence.

Format and Example(s):

BEGIN $

BEGIN ØPTIØNAL NAME ØF DMAP SEQUENCE $

Remarks:

1. This card is required at the beginning of a DMAP sequence. It must be the first card. The statement is included at the beginning of the DMAP sequence defining a Rigid Format. The user must provide the card as part of a user supplied DMAP sequence when using the DMAP approach.

2. This statement, like all DMAP statements, is terminated with the $ character delimiter.

3. This statement is a non-executable instruction for the DMAP compiler. (See Section 5.7 for an alternate Module XDMAP.)

4. For specific instructions related to DMAP useage, see Section 5.2.

Executive Control Card CEND - Executive Control Deck Terminator

Description: Defines the end of the Executive Control deck.

Format and Example(s):

CEND

Remarks: 1. This card is mandatory and must be last in the Executive Control Deck.

Executive Control Card CHKPNT - Checkpoint File Request

Description: Requests data blocks to be written to a checkpoint file for a later restart.

Format and Example(s):

CHKPNT $\begin{Bmatrix} \text{YES} \\ \underline{\text{NØ}} \end{Bmatrix}$

CHKPNT YES

Remarks:

1. This card is optional but when used, the checkpoint file must be made available by the user via operating system control cards.
2. The restart dictionary deck is automatically punched for use in a later restart execution.

Executive Control Card DIAG - Diagnostic Output and Operation Request

Description: Requests additional information to be printed out or requests executive operations to be performed.

Format and Example(s):

DIAG {n}

DIAG 14

DIAG 8,11,13

Option	Meaning
n	Integer to choose type of diagnostic (see Remarks)

Remarks: 1. One or more diagnostics may be chosen from the following table:

n	Diagnostic
1	Dump memory when fatal message is generated.
2	Print File Allocation Table (FIAT) following each call to the File Allocator.
3	Print status of the Data Pool Dictionary (DPD) following each call to the Data Pool Housekeeper.
4	Print the Operation Sequence Control Array (ØSCAR). See also Remark 3.
5	Print BEGIN time on-line for each functional module.
6	Print END time on-line for each functional module.
7	Print eigenvalue extraction diagnostics for real and complex determinant methods.
8	Print matrix and table data block trailers as they are generated.
9	Suppress echo of checkpoint dictionary.
10	Use alternate nonlinear loading in TRD. (Replace $\{N_{n+1}\}$ by $\frac{1}{3}\{N_{n+1} + N_n + N_{n-1}\}$)
11	Print all active row and column possibilities for decomposition algorithms.
12	Print eigenvalue extraction diagnostics for complex inverse power or FEER methods.
13	Print open core length.
14	Print the DMAP sequence that is compiled (NASTRAN SØURCE PRØGRAM CØMPILATIØN). See also Remarks 3 and 5.
15	Trace GINØ ØPEN/CLØSE operations.
16	Trace real inverse power eigenvalue extraction operations or eigensolution diagnostics for FEER tridiagonalization.
17	Punch the DMAP sequence that is compiled. See also Remark 3.

18	Trace Heat Transfer iterations (APP HEAT) or print grid point ID conversions from SET2 card (APP AERØ).
19	Print data for MPYAD method selection.
20	Generate de-bug printout (for NASTRAN programmers who include CALL BUG in their subroutines).
21	Print GP2 set definition.
22	Print GP4 degree of freedom definition.
23	Print the DMAP alters generated during Automated Multi-state Substructuring.
24	Punch the DMAP alters generated during Automated Multi-stage Substructuring.
25	Print a cross reference listing of the DMAP program that is compiled. See also Remarks 3 and 5.
26	Not used.
27	Input File Processor (IFP) table dump.
28	Punch the FØRTRAN code for the link specification table (subroutine XLNKDD). See Remark 4.
29	Process link specification table update deck. See Remark 4.
30	Punch FØRTRAN alters to the XSEMi decks (i set via DIAG 1-15). See Remark 4.
31	Print link specification table and module properties list data. See Remark 4.
32	Print a list of degrees of freedom including fluid point definitions. For each degree of freedom, the sets to which it belongs are identified.
33	Print the contents of various displacement sets. For each set, a list of degrees of freedom belonging to that set is given.

2. Multiple options may be selected by using multiple integers separated by commas or by using multiple DIAG cards.

3. See the description of the XDMAP card in Section 5.7 for alternate means of controlling the DMAP compiler options.

4. Refer to Section 6.11.3 of the Programmer's Manual for the description and use of DIAGs 28 through 31.

5. DIAG 14 is automatically turned on when DIAG 25 is requested.

Executive Control Card END - DMAP Sequence Terminator

Description: Defines the end of a Direct Matrix Abstraction Program (DMAP) sequence.

Format and Example(s):

END$

Remarks:

1. This card is required at the end of a DMAP sequence. It must be the last card. The statement is included at the end of the DMAP sequence defining a Rigid Format. The user must provide the card as part of a user supplied DMAP sequence when using the DMAP approach.

2. This statement, like all DMAP statements, is terminated with the $ character delimiter.

3. For specific instructions related to DMAP useage, see Section 5.2.

4. The END $ statement cannot be altered into a Rigid Format at intermediate steps. To schedule an early termination, use either the EXIT $ statement or the JUMP, FINIS $ statement.

Executive Control Card ENDALTER - Rigid Format DMAP Alter Terminator

Description: Defines the end of a user supplied alter to a Rigid Format Direct Matrix Abstraction Program (DMAP) sequence.

Format and Example(s):

ENDALTER

Remarks:

1. This card is required when an alter to a Rigid Format DMAP sequence is supplied.
2. The card is required only once but must be the last card for all alters.
3. For specific instructions related to DMAP useage, see Section 5.2.

EXECUTIVE CONTROL DECK

Executive Control Card ID - Job Identification

Description: Provides an alphanumeric identification of the job and establishes the beginning of the Executive Control deck.

Format and Example(s):

ID {A1,A2}

ID   A1234567,B7654321

Option	Meaning
A1	Any alphanumeric field chosen by the user for identification.
A2	Any alphanumeric field chosen by the user for identification.

Remarks:

1. This card is mandatory and must be first in the Executive Control deck.
2. The ID used during a checkpoint is automatically written to the checkpoint file and is placed on the restart card.
3. The first character of each field must be alphabetic and may be followed by up to seven alphanumeric characters.

Executive Control Card NUMF - New User Master File Declaration

Description: Defines a bulk data deck to be placed on a User Master File.

Format and Example(s):

NUMF {tid, pid}
NUMF 20012,6
NUMF 150,0

Option	Meaning
tid	User specified tape identification number assigned during the creation of a User's Master File.
pid	User specified problem identification number assigned during the creation of a User's Master File.

Remarks:

1. This card is required when the UMF Editor is in the write mode.
2. For specific instructions related to the UMF, see Section 2.5.

Executive Control Card RESTART - Restart Dictionary Initiator

Description: Defines the beginning of a restart dictionary deck when reading data blocks from the previously checkpointed file.

Format and Example(s):

RESTART {A1,A2,K1/K2/K3,K4,}

RESTART A1234567,B7654321,03/01/76,32400,

Option	Meaning
A1, A2	Fields taken from ID card of previously checkpointed problem.
K1/K2/K3	Month/Day/Year that Problem Tape was generated.
K4	Number of seconds after midnight at which XCSA begins execution.

Remarks:

1. The complete restart dictionary consists of this card followed by one card for each file checkpointed. The restart dictionary is automatically punched when operating in the checkpoint mode. All subsequent cards are continuations of this logical card. The entire dictionary deck is required for a restart.

2. Each continuation card begins with a sequence number. There are two types of continuation cards which are required and one that is not.

   Basic continuation card:

   NØ,DATABLØCK,FLAG=Y,REEL=Z,FILE=W

   where: NØ is the sequence number of the card. The entire dictionary must be in sequence by this number.

   DATABLØCK is the name of the data block referenced by this card.

   FLAG=Y defines the status of the data block where Y = 0 is the normal case and Y = 4 implies this data block is equivalenced to another data block. In this case (FLAG=4) the file number points to a previous data block which is the "actual" copy of the data.

   REEL=Z specifies the reel number as the Problem Tape can be a multi-reel tape. Z = 1 is the normal case.

   FILE=W specifies the GINØ (internal) file number of the data block on the Problem Tape. A zero value indicates the data block is purged. For example:

   1,GPL,FLAGS=0,REEL=1,FILE=7 says data block GPL occupies file 7 of reel 1.

   2,KGG,FLAGS=4,REEL=1,FILE=20 says KGG is equivalenced to the data block which occupies file 20. (Note that FLAGS=4 cards usually occur in at least pairs as the equivalenced operation is at least binary).

   3,USETD,FLAGS=0,REEL=1,FILE=0 implies USETD is purged.

Reentry point card:

NØ,REENTER AT DMAP SEQUENCE NUMBER N

where: NØ is the sequence number of the card.

N is the sequence number associated with the DMAP instruction at which an unmodified restart will resume execution. There may be (generally, there are) several reentry cards in a restart dictionary, but only the last such card is operative. (See Sections 3.1.3 and 3.1.4.)

End of dictionary card:

$ END ØF CHECKPØINT DICTIØNARY

This card is simply a comment card but is punched to signal the end of the dictionary for user convenience. The program does not need such a card. Terminations associated with non-NASTRAN failures (operator intervention, maximum time, etc.) will not have a card punched.

3. The previously checkpointed file must be made available by the user via operating system control cards.

4. A restart card of the form

   RESTART A1,A2, 0/0/0, 0

   can be used to read and process the Old Problem Tape (ØPTP) of any previously checkpointed problem whose ID card fields match the A1,A2 fields on this card.

5. A restart using the checkpointed file and dictionary created on a previous release of NASTRAN may not always be successful. First, the BUFFSIZE (the number of words in a GINØ buffer; see Section 2.1) used on the later release may be different from that used on the earlier release. Second, any changes that might have been made to the rigid formats may effectively destroy the validity of the restart dictionary.

6. See Sections 3.1.3, 3.1.4 and 3.1.5 for a detailed discussion of restarts.

Executive Control Card SØL - Solution Number Selection

Description: Selects the solution number which defines the Rigid Format.

Format and Example(s):

$$\text{SØL} \left\{ \begin{matrix} \text{K1} \\ \text{A} \end{matrix} \left[\begin{matrix} \text{K2} \\ ,\underline{0} \end{matrix} \right] \right\}$$

SØL 5

SØL 1,6

SØL 1,6,7,8,9

SØL STEADY STATE

Option	Meaning
K1	Solution number of Rigid Format (see Remarks below and Section 3).
K2	Subset numbers for solution K1, default value = 0.
A	Name of Rigid Format (see Remarks below).

Remarks:

1. When a Direct Matrix Abstraction Program (DMAP) is not used, the solution is mandatory. The subset associated with a solution is optional.

2. For Displacement Approach Rigid Formats, the integer value for K1 or the alphabetic characters for A must be selected from the following table:

K1	A
1	STATICS
2	INERTIA RELIEF
3	MØDES or NØRMAL MØDES or REAL EIGENVALUES
4	DIFFERENTIAL STIFFNESS
5	BUCKLING
6	PIECEWISE LINEAR
7	DIRECT CØMPLEX EIGENVALUES
8	DIRECT FREQUENCY RESPØNSE
9	DIRECT TRANSIENT RESPØNSE
10	MØDAL CØMPLEX EIGENVALUES
11	MØDAL FREQUENCY RESPØNSE
12	MØDAL TRANSIENT RESPØNSE
13	NØRMAL MØDES ANALYSIS WITH DIFFERENTIAL STIFFNESS
14	STATICS CYCLIC SYMMETRY
15	MØDES CYCLIC SYMMETRY

3. For Heat Approach Rigid Formats, the integer value for K1 or the alphabetic characters for A must be selected from the following table:

K1	A
1	STATICS
3	STEADY STATE
9	TRANSIENT

4. For Aero Approach Rigid Formats, the integer value for K1 or the alphabetic characters for A must be selected from the following table:

K1	A
10	MØDAL FLUTTER ANALYSIS
11	MØDAL AERØELASTIC RESPØNSE

5. Subsets cause a reduction in the number of statements in a Rigid Format. The use of a subset is optional. The integer value(s) may be selected from the following table:

K2	Subset Numbers
1	Delete loop control.
2	Delete mode acceleration method of data recovery (modal transient and modal frequency response).
3	Combine subsets 1 and 2.
4	Check all structural and aerodynamic data without execution of the aeroelastic problem.
5	Check only the aerodynamic data without execution of the aeroelastic problem.
6	Not used.
7	Delete structure plotting and X-Y plotting.
8	Delete Grid Point Weight Generator.
9	Delete fully stressed design (static analysis).

Multiple subsets may be selected by using multiple integers separated by commas.

Executive Control Card TIME - Maximum Execution Time Declaration

Description: Establishes the maximum time in minutes allotted to the execution of the NASTRAN program.

Format and Example(s):

TIME {n}

TIME 5

TIME 60

Option	Meaning
n	Integer number of minutes for execution.

Remarks:
1. This card is mandatory.
2. The time allotted via this card should be less than the time allotted the entire execution via operating system declaration.

30 8

Executive Control Card UMF - User Master File Selection

Description: Selects a bulk data deck stored on a User Master File.

Format and Example(s):

UMF {tid, pid}

UMF 20012,6

UMF 150,0

Option	Meaning
tid	Previously assigned tape identification number to access a Bulk Data Deck when using a User's Master File.
pid	Previously assigned problem identification number to access a Bulk Data Deck when using a User's Master File.

Remarks:

1. This card is required when the UMF Editor is in the read mode.
2. For specific instructions related to the UMF, see Section 2.5.

Executive Control Card UMFEDIT - User Master File Editor Selection

Description: Selects the UMF Editor and limits execution to the Preface only.

Format and Example(s):

UMFEDIT

Remarks:
1. This card is required to utilize the UMF Editor in a read or write mode.
2. Selection of the UMF Editor automatically limits execution to the Preface only, i.e., no computations may be performed when the Editor is used.
3. For specific instructions related to the UMF, see Section 2.5.

Executive Control Card $ - Comment Indicator

Description: Declares the character string is a non-executable comment.

Format and Example(s):

$ [any BCD string]

$ CØMMENTS MAY APPEAR IN ANY CØLUMNS

$ SPECIAL CHARACTERS MAY BE INCLUDED ( ) + . /

Remarks: 1. The $ character is a delimiter which allows comments to be written on the same physical card.

2.3 CASE CONTROL DECK

2.3.1 Data Selection

The Case Control cards that are used for selecting items from the Bulk Data Deck are listed below in functional groups. A detailed description of each card is given in Section 2.3.4. The first four characters of the mnemonic are sufficient if unique.

The following Case Control cards are associated with the selection of applied loads for both static and dynamic analysis:

1. DEFØRM - selects element deformation set.
2. DLØAD - selects dynamic loading condition.
3. DSCØEFFICIENT - selects loading factor for normal modes with differential stiffness.
4. LØAD - selects static structural loading condition or heat power and/or flux.
5. NØNLINEAR - selects nonlinear loading condition for transient response.
6. PLCØEFFICIENT - selects loading increments for piecewise linear analysis.

The following case control cards are used for the selection of constraints:

1. AXISYMMETRIC - selects boundary conditions for conical shell and axisymmetric solid elements or specifies the existence of fluid harmonics for a hydroelastic problem.
2. MPC - selects set of multipoint constraints for structural displacement or heat transfer boundary temperature relationships.
3. SPC - selects set of single-point constraints for structural displacements or heat transfer boundary temperatures.

The following case control cards are used for the selection of direct input matrices:

1. B2PP - selects direct input structural damping or thermal capacitance matrices.
2. K2PP - selects direct input structural stiffness or thermal conductance matrices.
3. M2PP - selects direct input mass matrices.
4. TFL - selects transfer functions.

The following case control cards specify the conditions for dynamic analyses:

1. CMETHØD - selects the conditions for complex eigenvalue extraction.
2. FREQUENCY - selects the frequencies to be used for frequency and random response calculations.
3. IC - selects the initial conditions for direct transient response.
4. METHØD - selects the conditions for real eigenvalue analysis.
5. RANDØM - selects the power spectral density functions to be used in random analysis.

6. SDAMPING - selects table to be used for determination of modal damping.

7. TSTEP - selects time steps to be used for integration in transient response problems.

8. FMETHØD - selects method to be used in aeroelastic flutter analysis.

9. GUST - selects aerodynamic gust loading in aeroelastic response analysis.

The following case control cards are associated with the use of thermal fields:

1. TEMPERATURE(LØAD) - selects thermal field to be used for determining equivalent static loads.

2. TEMPERATURE(MATERIAL) - selects thermal field to be used for determining structural material properties or an estimate of the temperature distribution for heat transfer iterations.

3. TEMPERATURE - selects thermal field for determining both equivalent static loads and material properties.

2.3.2 Output Selection

Printer output requests may be grouped in packets following ØUTPUT cards or the individual requests may be placed anywhere in the Case Control Deck ahead of any structure plotter or curve plotter requests. Plotter requests are described in Section 4. The Case Control cards that are used for output selection are listed below in functional groups. A detailed description of each card is given in Section 2.3.4.

The following cards are associated with output control, titling and bulk data echoes:

1. TITLE - defines a text to be printed on first line of each page of output.

2. SUBTITLE - defines a text to be printed on second line of each page of output.

3. LABEL - defines a text to be printed on third line of each page of output.

4. LINE - sets the number of data lines per printed page, default is 50 for 11-inch paper.

5. MAXLINES - sets the maximum number of output lines, default is 20,000.

6. ECHØ - selects echo options for Bulk Data Deck, default is a sorted bulk data echo.

The following cards are used in connection with some of the specific output requests for calculated quantities:

1. SET - defines lists of point numbers, elements numbers, or frequencies for use in output requests.

2. ØFREQUENCY - selects a set of frequencies to be used for output requests in frequency and aeroelastic response problems (default is all frequencies) or flutter velocities.

3. TSTEP - selects a set of time steps to be used for output requests in transient response problems.

4. ØTIME - selects a set of times to be used for output requests in transient analysis problems (default is all times).

The following cards are used to make output requests for the calculated response of components in the SØLUTIØN set (components in the direct or modal formulation of the general K system) for dynamics problems:

1. SACCELERATIØN - requests the acceleration of the independent components for a selected set of points or modal coordinates.

2. SDISPLACEMENT - requests the displacements of the independent components for a selected set of points or modal coordinates or the temperatures of the independent components for a selected set of points in heat transfer.

3. SVELØCITY - requests the velocities of the independent components for a selected set of points or modal coordinates or the change in temperature with respect to time of the independent components for a selected set of points in heat transfer.

4. NLLØAD - requests the nonlinear loads for a selected set of physical points (grid points and extra points introduced for dynamic analysis) in transient response problems.

The following cards are used to make output requests for stresses and forces, as well as the calculated response of degrees of freedom used in the model:

1. FØRCE or ELFØRCE - requests the forces in a set of structural elements or the temperature gradients and fluxes in a set of structural or heat elements in heat transfer.

2. STRESS or ELSTRESS - requests the stresses in a set of structural elements or the velocity components in a fluid element in acoustic cavity analysis.

3. SPCFØRCES - requests the single-point forces of constraint at a set of points or the thermal power transmitted to a selected set of points in heat transfer.

4. ØLØAD - selects a set of applied loads for output.

5. ACCELERATIØN - requests the accelerations for a selected set of PHYSICAL points (grid, scalar and fluid points plus extra points introduced for dynamic analysis).

6. DISPLACEMENT - requests the displacements for a selected set of PHYSICAL points or the temperatures for a selected set of PHYSICAL points in heat transfer or the pressures for a selected set of PHYSICAL points in hydroelasticity.

7. VELØCITY - requests the velocities for a selected set of PHYSICAL points or the change in temperatures with respect to time for a selected set of PHYSICAL points in heat transfer.

8. HARMØNICS - controls the number of harmonics that will be output for requests associated with the conical shell, axisymmetric solids and hydroelastic problems.

9. ESE - requests structural element strain energies in Rigid Format 1.

10. GPFØRCE - requests grid point force balance due to element forces, forces of single point constraint, and applied loads in Rigid Format 1.

11. THERMAL -- requests temperatures for a set of PHYSICAL points in heat transfer.

12. PRESSURE - requests pressures for a set of PHYSICAL points in hydroelasticity.

13. VECTØR - requests displacements for a selected set of PHYSICAL points.

14. MPCFØRCES - requests multipoint forces of constraint at a set of points in Rigid Formats 1, 2, 3, 14, and 15.

15. NCHECK - requests significant digits to indicate numerical accuracy of element stress and force computations.

16. AERØFØRCE - requests frequency dependent aerodynamic laods on interconnection points in aeroelastic response analysis.

17. STRAIN - requests the strains/curvatures in a set of structural elements (applicable to TRIA1, TRIA2, QUAD1, and QUAD2 only).

2.3.3 Subcase Definition

In general, a separate subcase is defined for each loading condition. In statics problems separate subcases are also defined for each set of constraints. In complex eigenvalue analysis and frequency response separate subcases are defined for each unique set of direct input matrices. Subcases may be used in connection with output requests, such as in requesting different output for each mode in a real eigenvalue problem.

The Case Control Deck is structured so that a minimum amount of repetition is required. Only one level of subcase definition is necessary. All items placed above the subcase level (ahead of the first subcase) will be used for all following subcases, unless overridden within the individual subcase.

In statics problems, subcases may be combined through the use of the SUBCØM feature. Individual loads may be defined in separate subcases and then combined by the SUBCØM. If the loads are mechanical, the responses are combined as shown in example 2, which follows. If a thermal load is involved, the responses due to mechanical and thermal loads may be recovered as shown in example 1. By redefining the thermal load(s) at the SUBCØM level, stresses and forces may be recovered.

In static problems, provision has been made for the combination of the results of several subcases. This is convenient for studying various combinations of individual loading conditions and for the superposition of solutions for symmetrical and antisymmetrical boundaries.

Typical examples of subcase definition are given following a brief description of the cards used in subcase definitions.

The following case control cards are associated with subcase definition:

1. <u>SUBCASE</u> - defines the beginning of a subcase that is terminated by the next subcase delimiters encountered.

2. <u>SUBCØM</u> - defines a combination of two or more immediately preceding subcases in statics problems. Output requests above the subcase level are used.

3. <u>SUBSEQ</u> - must appear in a subcase defined by SUBCØM to give the coefficients for making the linear combination of the preceding subcases.

4. <u>SYM</u> - defines a subcase in statics problems for which only output requests within the subcase will be honored. Primarily for use with symmetry problems where the individual parts of the solution may not be of interest.

5. <u>SYMCØM</u> - defines a combination of two or more immediately preceding SYM subcases in static problems. Output requests above the subcase level are used.

6. <u>SYMSEQ</u> - may appear in a subcase defined by SYMCØM to give the coefficient for making the linear combination of the preceeding SYM subcases. A default value of 1.0 is used if no SYMSEQ card appears.

7. <u>REPCASE</u> - defines a subcase in statics problems that is used to make additional output requests for the previous real subcase. This card is required because multiple output requests for the same item are not permitted in the same subcase. Output requests above the subcase level are still used.

8. <u>MØDES</u> - controls the output for a given subcase as specified by the number of modes, otherwise all modes will be used.

The following examples of Case Control Decks indicate typical ways of defining subcases:

1. Static analysis with multiple loads.

```
ØUTPUT
    DISPLACEMENT = ALL
MPC = 3
    SUBCASE 1
        SPC = 2
        TEMPERATURE(LØAD) = 101
        LØAD = 11
    SUBCASE 2
        SPC = 2
        DEFØRM = 52
        LØAD = 12
    SUBCASE 3
        SPC = 4
        LØAD = 12
    SUBCASE 4
        MPC = 4
        SPC = 4
```

Four subcases are defined in this example. The displacements at all grid points will be printed for all four subcases. MPC = 3 will be used for the first three subcases and will be overridden by MPC = 4 in the last subcase. Since the constraints are the same for subcases 1 and 2 and the subcases are contiguous, the static solutions will be performed simultaneously. In subcase 1, thermal load 101 and external load 11 are internally superimposed, as are the external and deformation loads in subcase 2. In subcase 4 the static loading will result entirely from enforced displacements of grid points.

2. Linear combination of subcases.

```
SPC = 2
ØUTPUT
    SET 1 = 1 THRU 10,20,30
    DISPLACEMENT = ALL
    STRESS = 1
SUBCASE 1
    LØAD = 101
    ØLØAD = ALL
SUBCASE 2
    LØAD = 201
    ØLØAD = ALL
SUBCØM 51
    SUBSEQ = 1.0,1.0
SUBCØM 52
    SUBSEQ = 2.5,1.5
```

Two static loading conditions are defined in subcases 1 and 2. SUBCØM 51 defines the sum of subcases 1 and 2. SUBCØM 52 defines a linear combination consisting of 2.5 times subcase 1 plus 1.5 times subcase 2. The displacements at all grid points and the stresses for the elements numbers in SET will be printed for all four subcases. In addition, the nonzero components of the static load vectors will be printed for subcases 1 and 2.

3. Statics problem with one plane of symmetry.

```
ØUTPUT
    SET 1 = 1,11,21,31,51
    SET 2 = 1 THRU 10, 101 THRU 110
    DISPLACEMENT = 1
    ELFØRCE = 2
SYM 1
    SPC = 11
    LØAD = 21
    ØLØAD = ALL
SYM 2
    SPC = 12
    LØAD = 22
SYMCØM 3
SYMCØM 4
    SYMSEQ 1.0,-1.0
```

Two SYM subcases are defined in subcases 1 and 2. SYMCØM 3 defines the sum and SYMCØM 4 the

difference of the two SYM subcases. The nonzero components of the static load will be printed for subcase 1 and no output is requested for subcase 2. The displacements for the grid point numbers in set 1 and the forces for elements in set 2 will be printed for subcases 3 and 4.

4. Use of REPCASE in statics problems.

```
SET 1 = 1 THRU 10, 101 THRU 110, 201 THRU 210
SET 2 = 21 THRU 30, 121 THRU 130, 221 THRU 230
SET 3 = 31 THRU 40, 131 THRU 140, 231 THRU 240
    SUBCASE 1
        LØAD =10
        SPC = 11
        DISPLACEMENT = ALL
        SPCFØRCE = 1
        ELFØRCE = 1
    REPCASE 2
        ELFØRCE = 2
    REPCASE 3
        ELFØRCE = 3
```

This example defines one subcase for solution and two subcases for output control. The displacements at all grid points and the nonzero components of the single-point forces of constraint along with forces for the elements in SET 1 will be printed for SUBCASE 1. The forces for elements in SET 2 will be printed for REPCASE 2 and the forces for elements in SET 3 will be printed for REPCASE 3.

5. Use of MØDES in eigenvalue problems

```
    METHØD = 2
    SPC = 10
SUBCASE 1
    DISPLACEMENT = ALL
    STRESS = ALL
    MØDES = 2
SUBCASE 3
    DISPLACEMENT = ALL
```

In this example the displacements at all grid points will be printed for all modes. The stresses in all elements will be printed for the first two modes.

2.3.4 Case Control Card Descriptions

The format of the Case Control cards is free-field. In presenting general formats for each card embodying all options, the following conventions are used:

1. Upper-case letters and parentheses must be punched as shown.
2. Lower-case letters indicate that a substitution must be made.
3. Braces { } indicate that a choice of contents is mandatory.

4. Brackets [ ] contain an option that may be omitted or included by the user.

5. Underlined options or values are the default values.

6. Physical card consists of information punched in columns 1 thru 72 of a card. Most case control cards are limited to a single physical card.

7. Logical card may have more than 72 columns with the use of continuation cards. A continuation card is honored by ending the preceding card with a comma.

The structure plotter output request packet and the x-y output request packet, while part of the Case Control Deck, are treated separately in Sections 4.2 and 4.3, respectively.

Case Control Data Card - ACCELERATIØN - Acceleration Output Request.

Description: Requests form and type of acceleration vector output.

Format and Example(s):

$$\text{ACCELERATIØN}\left[\left(\begin{array}{c}\underline{\text{SØRT1}}\\ \text{SØRT2}\end{array},\begin{array}{c}\underline{\text{PRINT}}\\ \text{PUNCH}\end{array},\begin{array}{c}\underline{\text{REAL}}\\ \text{IMAG}\\ \text{PHASE}\end{array}\right)\right] = \left\{\begin{array}{c}\text{ALL}\\ n\\ \text{NØNE}\end{array}\right\}$$

ACCELERATIØN = 5

ACCELERATIØN(SØRT2, PHASE) = ALL

ACCELERATIØN(SØRT1, PRINT, PUNCH, PHASE) = 17

Option	Meaning
SØRT1	Output will be presented as a tabular listing of grid points for each load, frequency, eigenvalue, or time, depending on the rigid format. SØRT1 is not available in Transient problems (where the default is SØRT2).
SØRT2	Output will be presented as a tabular listing of frequency or time for each grid point. SØRT2 is available only in Transient and Frequency Response problems.
PRINT	The printer will be the output media.
PUNCH	The card punch will be the output media.
REAL or IMAG	Requests real and imaginary output on Frequency Response problems.
PHASE	Requests magnitude and phase ($0.0° \leq$ phase $< 360.0°$) on Frequency Response problems.
ALL	Accelerations for all points will be output.
n	Set identification of a previously appearing SET card. Only accelerations of points whose identification numbers appear on this SET card will be output (Integer > 0).
NØNE	Accelerations for no points will be output.

Remarks:

1. Both PRINT and PUNCH may be requested.
2. An output request for ALL in Transient and Frequency response problems generally produces large amounts of printout. An alternative to this would be to define a SET of interest.
3. Acceleration output is only available for Transient and Frequency Response problems.
4. In a frequency Response problem any request for SORT2 output causes all output to be SØRT2.
5. ACCELERATIØN = NØNE allows overriding an overall output request.

Case Control Data Card AERØF - Aerodynamic Force Output Request

Description: Requests the aerodynamic loads on the interconnection points.

Format and Example(s):

AERØF = n

AERØF = ALL

AERØF = 5

Option	Meaning
n	Set identification of a previously appearing SET card. Only aerodynamic forces on points referenced will be output.
ALL	Aerodynamic forces on all points will be output.

Remarks:

1. Only frequency-dependent forces may be requested (frequency response or random analysis).
2. The point identification numbers are the box or body element IDs.
3. The dimensions of the output are force (or moment) per unit dynamic pressure.

Case Control Data Card AXISYMMETRIC - Boundary Conditions or Hydroelastic Harmonics.

Description: Selects boundary conditions for problems containing CCØNEAX, CTRAPAX or CTRIAAX elements or specifies the existence of fluid harmonics for hydroelastic problems.

Format and Example(s):

$$\text{AXISYMMETRIC} = \begin{Bmatrix} \text{SINE} \\ \text{CØSINE} \\ \text{FLUID} \end{Bmatrix}$$

AXISYMMETRIC = CØSINE

Option	Meaning
SINE	Sine boundary conditions will be used.
CØSINE	Cosine boundary conditions will be used.
FLUID	Existence of fluid harmonics.

Remarks:
1. This card is required for problems containing the elements named above.
2. If this card is used for hydroelastic problems, at least one harmonic must be specified on the AXIF card.
3. See Section 1.3.6 of User's Manual for a discussion of the conical shell problem.
4. See Section 1.3.7 of User's Manual for a discussion of the axisymmetric solid problem.
5. See Section 1.7.1 of User's Manual for a discussion of the hydroelastic formulation.
6. The sine boundary condition will constrain components 1, 3 and 5 at every ring for the zero harmonic.
7. The cosine boundary condition will constrain components 2, 4 and 6 at every ring for the zero harmonic.
8. SPC and MPC case control cards may also be used to effect additional constraints.

Case Control Data Card BEGIN BULK - End of Case Control Deck

Description: Terminates the end of the Case Control Deck directives and controls. Cards appearing after this card are assumed to be Bulk Data Deck cards.

Format and Example(s):

ENDDATA

Remarks: 1. The ENDDATA card must begin in column 1 or 2.

Case Control Data Card <u>B2PP</u> - Direct Input Damping Matrix Selection.

<u>Description:</u> Selects a direct input damping matrix.

<u>Format and Example(s):</u>

B2PP = name

B2PP = BDMIG

B2PP = B2PP

<u>Option</u>	<u>Meaning</u>
name	BCD name of $[B^2_{pp}]$ matrix that is input on the DMIG or DMIAX bulk data card.

<u>Remarks:</u> 1. B2PP is used only in dynamics problems.

2. DMIG and DMIAX matrices will not be used unless selected.

Case Control Data Card CMETHØD - Complex Eigenvalue Extraction Method Selection.

Description: Selects complex eigenvalue extraction data to be used by module CEAD.

Format and Example(s):

CMETHØD = n

CMETHØD = 77

Option	Meaning
n	Set identification of EIGC (and EIGP) card (Integer > 0).

Remarks: Eigenvalue extraction data must be selected when extracting complex eigenvalues using Functional Module CEAD.

Case Control Data Card DEFØRM - Element Deformation Static Load.

Description: Selects the Element Deformation Set to be applied to the structural model.

Format and Example(s):

DEFØRM = n

DEFØRM = 27

Option	Meaning
n	Set identification of DEFØRM cards (Integer > 0).

Remarks:

1. DEFØRM bulk data cards will not be used unless selected in the Case Control Deck.
2. DEFØRM is only applicable in statics, inertia relief, differential stiffness, and buckling problems.
3. The total load applied will be the sum of external, (LØAD), thermal (TEMP(LØAD)), element deformation (DEFØRM) and constrained displacement loads (SPC).
4. Static, thermal and element deformation loads should have unique identification numbers.

Case Control Data Card DISPLACEMENT - Displacement Output Request.

Description: Requests form and type of displacement vector output.

Format and Example(s):

$$\text{DISPLACEMENT}\left[\left(\frac{\text{SØRT1}}{\text{SØRT2}},\ \frac{\text{PRINT}}{\text{PUNCH}},\ \begin{matrix}\frac{\text{REAL}}{\text{IMAG}}\\ \text{PHASE}\end{matrix}\right)\right] = \begin{Bmatrix}\text{ALL}\\ n\\ \text{NØNE}\end{Bmatrix}$$

DISPLACEMENT = 5

DISPLACEMENT(REAL) = ALL

DISPLACEMENT(SØRT2, PUNCH, REAL) = ALL

Option	Meaning
SØRT1	Output will be presented as a tabular listing of grid points for each load, frequency, eigenvalue, or time, depending on the rigid format. SØRT1 is not available in Transient problems (where the default is SØRT2).
SØRT2	Output will be presented as a tabular listing of load, frequency, or time for each grid point. SØRT2 is available only in Static Analysis, Transient and Frequency Response problems.
PRINT	The printer will be the output media.
PUNCH	The card punch will be the output media.
REAL or IMAG	Requests real and imaginary output on Complex Eigenvalue or Frequency Response problems.
PHASE	Requests magnitude and phase ($0.0° \le$ phase $< 360.0°$) on Complex Eigenvalue or Frequency Response problems.
ALL	Displacements for all points will be output.
NØNE	Displacements for no points will be output.
n	Set identification of previously appearing SET card. Only displacements of points whose identification numbers appear on this SET card will be output (Integer > 0).

Remarks:
1. Both PRINT AND PUNCH may be requested.
2. An output request for ALL in Transient and Frequency response problems generally produces large amounts of printout. An alternative to this would be to define a SET of interest.
3. In Static Analysis or Frequency Response problems, any request for SØRT2 causes all output to be SØRT2.
4. VECTØR, PRESSURE and THERMAL are alternate forms and are entirely equivalent to DISPLACEMENT.
5. DISPLACEMENT = NØNE allows overriding an overall output request.

Case Control Data Card DLØAD - Dynamic Load Set Selection.

Description: Selects the dynamic load to be applied in a Transient or Frequency Response problem.

Format and Example(s):

DLØAD = n

DLØAD = 73

Option	Meaning
n	Set identification of a DLØAD, RLØAD1, RLØAD2, TLØAD1, or TLØAD2 card (Integer > 0).

Remarks:

1. The above loads will not be used by NASTRAN unless selected in Case Control.
2. RLØAD1 and RLØAD2 may only be selected in a Frequency Response problem.
3. TLØAD1 and TLØAD2 may only be selected in a Transient Response problem.
4. Either RLØAD or TLØAD (but not both) may be selected in an Aeroelastic Response problem. If RLØAD is selected, a Frequency Response is calculated. If TLØAD is selected, then Transient Response is computed by Fourier Transform.

Case Control Data Card DSCØEFFICIENT - Differential Stiffness Coefficient Set.

Description: Selects the coefficient set for a Normal Modes with Differential Stiffness Problem.

Format and Example(s):

DSCØEFFICIENT = $\left\{\begin{matrix}\text{DEFAULT}\\ n\end{matrix}\right\}$

DSCØEF = 15

DSCØEF = DEFAULT

Option	Meaning
DEFAULT	A single default coefficient of value 1.0.
n	Set identification of DSFACT card (Integer > 0).

Remarks: 1. DSFACT cards will not be used unless selected.

2. DSCØEFFICIENT must appear in the 2nd Subcase of a Normal Modes with Differential Stiffness problem.

Case Control Data Card ECHØ - Bulk Data Echo Request.

Description: Requests echo of bulk data deck.

Format and Example(s):

$$\text{ECHØ} = \begin{bmatrix} \text{SØRT} \\ \text{UNSØRT} \\ \text{BØTH} \\ \text{NØNE} \\ \text{PUNCH} \end{bmatrix} \text{ (see Remark 1 for default values)}$$

ECHØ = BØTH

ECHØ = PUNCH, SØRT

Option	Meaning
SØRT	Sorted echo will be printed.
UNSØRT	Unsorted echo will be printed.
BØTH	Both sorted and unsorted echo will be printed.
NØNE	No echo will be printed.
PUNCH	The sorted bulk data deck will be punched onto cards.

REMARKS:

1. If no ECHØ card appears, ECHØ = BØTH is assumed for restart runs and for runs employing the UMF. For all other runs, ECHØ = SØRT is assumed.
2. If CHKPNT YES is specified, a sorted echo will be printed unless ECHØ = NØNE.
3. Unrecognizable options will be treated as SØRT.
4. Any option overrides the default. Thus, for example, if both print and punch are desired, both SØRT and PUNCH must be requested on the same card.
5. The NØNE option cannot be combined with the PUNCH option. If punch output only is desired, ECHØ = PUNCH will suffice.

Case Control Data Card <u>ELFØRCE</u> - Element Force Output Request.

<u>Description</u>: Requests form and type of element force output.

<u>Format and Example(s)</u>:

$$\text{ELFØRCE}\ \left[\left(\frac{\text{SØRT1}}{\text{SØRT2}},\ \frac{\text{PRINT}}{\text{PUNCH}},\ \begin{matrix}\underline{\text{REAL}}\\ \underline{\text{IMAG}}\\ \text{PHASE}\end{matrix}\right)\right] = \left\{\begin{matrix}\text{ALL}\\ n\\ \text{NØNE}\end{matrix}\right\}$$

ELFØRCE = ALL

ELFØRCE(REAL, PUNCH, PRINT) = 17

ELFØRCE = 25

<u>Option</u>	<u>Meaning</u>
SØRT1	Output will be presented as a tabular listing of elements for each load, frequency, eigenvalue, or time, depending on the rigid format. SØRT1 is not available in Transient problems (where the default is SØRT2).
SØRT2	Output will be presented as a tabular listing of load, frequency, or time for each element type. SØRT2 is available only in Static Analysis, Transient and Frequency Response problems.
PRINT	The printer will be the output media.
PUNCH	The card punch will be the output media.
REAL or IMAG	Requests real and imaginary output on Complex Eigenvalue or Frequency Response problems.
PHASE	Requests magnitude and phase ($0.0° \le \text{phase} < 360.0°$) on Complex Eigenvalue or Frequency Response problems.
ALL	Forces for all elements will be output.
NØNE	Forces for no elements will be output.
n	Set identification of a previously appearing SET card. Only forces of elements whose identification numbers appear on this SET card will be output (Integer > 0).

<u>Remarks</u>:

1. Both PRINT and PUNCH may be requested.
2. An output request for ALL in Transient and Frequency response problems generally produces large amounts of printout. An alternative to this would be to define a SET of interest.
3. In Static Analysis or Frequency Response problems, any request for SØRT2 output causes all output to be SØRT2.
4. FØRCE is an alternate form and is entirely equivalent to ELFØRCE.
5. ELFØRCE = NØNE allows overriding an overall request.
6. In heat transfer analysis, ELFØRCE output consists of heat flow through and out of the elements.

Case Control Data Card ELSTRESS - Element Stress Output Request.

Description: Requests form and type of element stress output.

Format and Example(s):

$$\text{ELSTRESS}\quad \left[\left(\frac{\text{SØRT1}}{\text{SØRT2}},\ \frac{\text{PRINT}}{\text{PUNCH}},\ \frac{\text{REAL}}{\frac{\text{IMAG}}{\text{PHASE}}}\right)\right] = \left\{\begin{matrix}\text{ALL}\\ n\\ \text{NØNE}\end{matrix}\right\}$$

ELSTRESS = 5

ELSTRESS = ALL

ELSTRESS(SØRT1, PRINT, PUNCH, PHASE) = 15

Option	Meaning
SØRT1	Output will be presented as a tabular listing of elements for each load, frequency, eigenvalue, or time, depending on the rigid format. SØRT1 is not available in Transient problems (where the default is SØRT2).
SØRT2	Output will be presented as a tabular listing of load, frequency, or time for each element type. SØRT2 is available only in Static Analysis, Transient and Frequency Response problems.
PRINT	The printer will be the output media.
PUNCH	The card punch will be the output media.
REAL or IMAG	Requests real and imaginary printout on Complex Eigenvalue or Frequency Response problems.
PHASE	Requests magnitude and phase ($0.0° \leq \text{phase} < 360.0°$) on Complex Eigenvalue or Frequency Response problems.
ALL	Stresses for all elements will be output.
n	Set identification of a previously appearing SET card (Integer > 0). Only stresses for elements whose identification numbers appear on this SET card will be output.
NØNE	Stress for no elements will be output.

Remarks:

1. Both PRINT and PUNCH may be requested.
2. An output request for ALL in Transient and Frequency response problems generally produces large amounts of printout. An alternative to this would be to define a SET of interest.
3. In Static Analysis or Frequency Response problems, any request for SØRT2 output causes all output to be SØRT2.
4. STRESS is an alternate form and is entirely equivalent to ELSTRESS.
5. ELSTRESS = NØNE allows overriding an overall output request.
6. If element stresses in material coordinate system are desired (only for TRIA1, TRIA2, QUAD1 and QUAD2 elements and only in Rigid Format 1), the parameter STRESS (see the description of the PARAM bulk data card in Section 2.4.2) should be set to be a positive integer. If, in addition to element stresses in material coordinate system, stresses at the connected grid points are also desired, the parameter STRESS should be set to 0.

Case Control Data Card ESE - Element Strain Energy Output Request

Description: Requests strain energy output and per cent of total strain energy with respect to all elements.

Format and Example(s):

$$\text{ESE} \left[\begin{pmatrix}\text{PRINT}\\\text{PUNCH}\end{pmatrix}\right] = \begin{Bmatrix}\text{ALL}\\ n\\ \text{NØNE}\end{Bmatrix}$$

ESE (PUNCH) = 5

ESE (PRINT,PUNCH) = ALL

Option	Meaning
PRINT	The printer will be the output media.
PUNCH	The card punch will be the output media.
ALL	Strain energies will be output for all elements for which stiffness matrices exist.
NØNE	Strain energies for no elements will be output.
n	Set identification of previously appearing SET card (Integer >0). Only strain energies for elements whose identification numbers appear on this SET card will be output.

Remarks:

1. Element strain energies are output from Static Analysis (Rigid Format 1) only.
2. The output will be in SØRT 1 format.
3. Both PRINT and PUNCH may be requested.
4. ESE = NØNE allows overriding an overall output request.

Case Control Data Card FMETHØD -Flutter Analysis Method

Description: Selects the FLUTTER parameters to be used by the flutter module (FA1).

Format and Example(s):

FMETHØD = n
FMETHØD = 72

Option	Meaning
n	Set identification number of a FLUTTER card (integer > 0).

Remarks: 1. A FMETHØD card is required for flutter analysis.

Case Control Data Card FØRCE - Element Force Output Request.

Description: Requests form and type of element force output.

Format and Example(s):

$$\text{FØRCE} \quad \left[\left(\frac{\text{SØRT1}}{\text{SØRT2}}, \frac{\text{PRINT}}{\text{PUNCH}}, \frac{\text{REAL}}{\frac{\text{IMAG}}{\text{PHASE}}}\right)\right] = \begin{Bmatrix}\text{ALL}\\ \text{n}\\ \text{NØNE}\end{Bmatrix}$$

FØRCE = ALL

FØRCE(REAL, PUNCH, PRINT) = 17

FØRCE = 25

Option	Meaning
SØRT1	Output will be presented as a tabular listing of elements for each load, frequency, eigenvalue, or time, depending on the rigid format. SØRT1 is not available in Transient problems (where the default is SØRT2).
SØRT2	Output will be presented as a tabular listing of load, frequency, or time for each element type. SØRT2 is available only in Static Analysis, Transient and Frequency Response problems.
PRINT	The printer will be the output media.
PUNCH	The card punch will be the output media.
REAL or IMAG	Requests real and imaginary printout on Complex Eigenvalue or Frequency Response problems.
PHASE	Requests magnitude and phase ($0.0° \leq$ phase $< 360.0°$) on Complex Eigenvalue or Frequency Response problems.
ALL	Forces for ALL elements will be output.
n	Set identification of a previously appearing SET card. Only forces whose element identification numbers appear on this SET card will be output (Integer > 0).
NØNE	Forces for no elements will be output.

Remarks:

1. Both PRINT and PUNCH may be requested.
2. An output request for ALL in Transient and Frequency response problems generally produces large amounts of printout. An alternative to this would be to define a SET of interest.
3. In Static Analysis or Frequency Response problems, any request for SØRT2 output causes all output to be SØRT2.
4. ELFØRCE is an alternate form and is entirely equivalent to FØRCE.
5. FØRCE = NØNE allows overriding an overall request.
6. In heat transfer analysis, ELFØRCE output consists of heat flow through and out of the elements.

Case Control Data Card FREQUENCY - Frequency Set Selection

Description: Selects the set of frequencies to be solved in Frequency Response problems.

Format and Example(s):

FREQUENCY = n
FREQUENCY = 17

Option	Meaning
n	Set identification of a FREQ, FREQ1 or FREQ2 type card (Integer > 0).

Remarks:
1. The FREQ, FREQ1 or FREQ2 cards will not be used unless selected in Case Control.
2. A frequency set selection is required for a Frequency Response problem.
3. A frequency set selection is required for Transient Response by Fourier methods.

Case Control Data Card GPFØRCE - Grid Point Force Balance Output Request

Description: Requests grid point force balance output from applied loads, single-point constraints, and element contraints.

Format and Example (s):

$$\text{GPFØRCE} \quad \left[\left(\frac{\text{PRINT}}{\text{PUNCH}}\right)\right] = \left\{\begin{matrix}\text{ALL}\\ \text{n}\\ \text{NØNE}\end{matrix}\right\}$$

Option	Meaning
PRINT	The printer will be the output media.
PUNCH	The card punch will be the output media.
ALL	Force balance will be output for all elements connected to grid points or scalar points.
NØNE	Force balance for no grid points will be output.
n	Set identification of previously appearing SET card (Integer >0). Only force balance for points whose identification numbers appear on this SET card will be output.

Remarks:

1. Grid point force balance is output from Statics Analysis (Rigid Format 1) only.
2. The output will be in SØRT 1 format.
3. Both PRINT and PUNCH may be requested.
4. GPFØRCE = NØNE allows overriding an overall output request.

Case Control Data Card GUST - Aerodynamic Gust Load Request

Description: Selects the gust field in an Aeroelastic Response problem.

Format and Example(s):

GUST = n

GUST = 73

Option	Meaning
n	Set identification of a GUST bulk data card (Integer > 0).

Remarks:
1. The above gust will not be used by NASTRAN unless selected in Case Control.
2. The choice of transient or frequency response gust depends upon the type of TLØAD or RLØAD referenced on the selected GUST card.

Case Control Data Card HARMØNICS - Harmonic Printout Control.

Description: Controls number of harmonics output for problems containing CCØNEAX, CTRAPAX or CTRIAAX elements.

Format and Example(s):

$$\text{HARMONICS} = \left\{\begin{array}{c}\text{ALL}\\ \text{NØNE}\\ n\\ \underline{0}\end{array}\right\}$$

Option	Meaning
ALL	All Harmonics will be output.
NØNE	No Harmonics will be output.
n	Available harmonics up to and including n will be output (Integer $\geq$ 0).

Remarks: If no HARMØNICS card appears in Case Control, only 0 harmonic output will be printed.

Case Control Data Card IC - Transient Initial Condition Set Selection.

Description: To select the initial conditions for Direct Transient problems.

Format and Example(s):

IC = n

IC = 17

Option	Meaning
n	Set identification of TIC card (Integer > 0) for structural analysis. Set identification of TEMP and/or TEMPD card (Integer > 0) for heat transfer analysis.

Remarks:

1. TIC cards will not be used (hence no initial conditions) unless selected in Case Control.

2. Initial conditions are not allowed in a Modal Transient problem.

Case Control Data Card K2PP - Direct Input Stiffness Matrix Selection.

Description: Selects a direct input stiffness matrix.

Format and Example(s):

K2PP = name

K2PP = KDMIG

K2PP = K2PP

Option	Meaning
name	BCD name of a $[K^{2d}_{pp}]$ matrix that is input on the DMIG or DMIAX bulk data card.

Remarks: 1. K2PP is used only in dynamics problems.

2. DMIG and DMIAX matrices will not be used unless selected.

Case Control Data Card LABEL - Output Label.

Description: Defines a BCD label which will appear on the third heading line of each page of NASTRAN printer output.

Format and Example(s):

LABEL = { Any BCD data }

LABEL = SAMPLE ØF A LABEL CARD

Remarks:
1. LABEL appearing at the subcase level will label output for that subcase only.
2. LABEL appearing before all subcases will label any outputs which are not subcase dependent.
3. If no LABEL card is supplied, the label line will be blank.
4. LABEL information is also placed on NASTRAN plotter output as applicable.

Case Control Data Card LINE - Data Lines Per Page.

Description: Defines the number of data lines per printed page.

Format and Example(s):

LINE = $\begin{Bmatrix} 42 \\ n \end{Bmatrix}$ IBM and CDC

LINE = $\begin{Bmatrix} 50 \\ n \end{Bmatrix}$ UNIVAC and DEC VAX

Option	Meaning
n	Number of data lines per page (Integer ≥ 10).

Remarks:

1. If no LINE card appears, the appropriate default is used.
2. For 11 inch paper, 50 is the recommended number; for 8-1/2 inch paper, 35 is the recommended number.
3. Alternatively, the number of data lines per printed page can also be defined by means of the NLINES keyword on the NASTRAN card (see Section 2.1).

Case Control Data Card LØAD - External Static Load Set Selection.

Description: Selects the external static load set to be applied to the structural model.

Format and Example(s):

LØAD = n

LØAD = 15

Option	Meaning
n	Set identification of at least one external load card and hence must appear on at least one FØRCE, FØRCE1, FØRCE2, MØMENT, MØMENT1, MØMENT2, GRAV, PLØAD, PLØAD2, PLØAD3, RFØRCE, PRESAX, FØRCEAX, MØMAX, SLØAD, or LØAD card (Integer > 0).

Remarks:

1. The above static load cards will not be used by NASTRAN unless selected in Case Control.

2. A GRAV card cannot have the same set identification number as any of the other loading card types. If it is desired to apply a gravity load along with other static loads, a LØAD bulk data card must be used.

3. If n is to be the set identification number of a bulk data LØAD card (see description in Section 2.4), then it must be different from the load set identification numbers of all external static load sets in the Bulk Data Deck.

4. LØAD is only applicable in statics, inertia relief, differential stiffness, buckling and piecewise linear problems.

5. The total load applied will be the sum of external (LØAD), thermal (TEMP(LØAD)), element deformation (DEFØRM) and constrained displacement (SPC) Loads.

6. Static, thermal and element deformation loads must have unique set identification numbers.

7. The rigid formats that accept a static load card expect it to appear in the Case Control Deck in a certain place with respect to subcase definitions. See Section 3 for specific instructions.

Case Control Data Card M2PP - Direct Input Mass Matrix Selection.

Description: Selects a direct input mass matrix.

Format and Example(s):

M2PP = name

M2PP = MDMIG

M2PP = M2PP

Option	Meaning
name	BCD name of a $[M_{pp}^{2d}]$ matrix that is input on the DMIG or DMIAX bulk data card.

Remarks:

1. M2PP is supported only in dynamics problems.
2. DMIG and DMIAX matrices will not be used unless selected.

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Case Control Data Card MAXLINES - Maximum Number of Output Lines.

Description: Sets the maximum number of output lines to a given value.

Format and Example(s):

$$\text{MAXLINES} = \left\{\begin{matrix}\underline{20000} \\ n\end{matrix}\right\}$$

MAXLINES = 50000

Option	Meaning
n	Maximum number of output lines which the user wishes to allow (Integer > 0).

Remarks:

1. Any time this number is exceeded, NASTRAN will terminate thru PEXIT.
2. This card may or may not override system operating control cards. Users should check with the local operations staff.

Case Control Data Card METHØD - Real Eigenvalue Extraction Method Selection.

Description: Selects the Real Eigenvalue Parameters to be used by the READ module.

Format and Example(s):

METHØD = n

METHØD = 33

Option	Meaning
n	Set identification number of an EIGR card (normal modes or modal formulation) or an EIGB card (Buckling). (Integer > 0)

Remarks: 1. An eigenvalue extraction method must be selected when extracting real eigenvalues using Functional Module READ.

2. Each of the rigid formats that accept an eigenvalue method card expect it to appear in the Case Control Deck in a certain place with respect to subcase definitions. See Section 3 for specific instructions.

Case Control Data Card MØDES - Duplicate Case Control.

Description: Repeats case control MØDES times - to allow control of output in eigenvalue problems.

Format and Example(s):

MØDES = n

MØDES = 1

Option	Meaning
n	Number of modes, starting with the first and proceeding sequentially upward, for which the case control or subcase control is to apply. (Integer > 0).

Remarks: 1. This card can be illustrated by an example. Suppose stress output is desired for the first five modes only and Displacements only thereafter. The following example would accomplish this:

```
SUBCASE 1
MØDES = 5
ØUTPUT
STRESS = ALL
SUBCASE 6
ØUTPUT
DISPLACEMENTS = ALL
BEGIN BULK
```

2. The MØDES card causes the results for each eigenvalue to be considered as a separate, successively numbered subcase, beginning with the subcase number containing the MØDES card.

3. If the MØDES card is not used, eigenvalue results are considered to be a part of a single subcase. Hence, any output requests for the single subcase will apply for all eigenvalues.

4. All eigenvectors with mode numbers greater than the number of records in Case Control are printed with the descriptors of the last Case Control record. For example, to suppress all printout for modes beyond the first three, the following Case Control deck could be used:

```
SUBCASE 1
MØDES = 3
DISPLACEMENTS = ALL
SUBCASE 4
DISPLACEMENTS = NØNE
BEGIN BULK
```

Case Control Data Card MPC - Multipoint Constraint Set Selection.

Description: Selects the multipoint constraint set to be applied to the structural model.

Format and Example(s):

MPC = n

MPC = 17

Option	Meaning
n	Set identification of a Multipoint-Constraint Set and hence must appear on at least one MPC, MPCADD, MPCAX, or MPCS card. (Integer > 0).

Remarks: MPC, MPCADD, MPCAX, or MPCS cards will not be used by NASTRAN unless selected in Case Control.

Case Control Data Card MPCFØRCES - Multipoint Forces of Constraint Output Request

Description: Requests multipoint force of constraint vector output.

Format and Example(s):

$$\text{MPCFØRCES} \left[\left(\text{SØRT1}, \frac{\text{PRINT}}{\text{PUNCH}} \right) \right] = \left\{ \begin{matrix} \text{ALL} \\ n \\ \text{NØNE} \end{matrix} \right\}$$

MPCFØRCE = 10

MPCFØRCE(PRINT,PUNCH) = ALL

MPCFØRCE = NØNE

Option	Meaning
SØRT1	Output will be presented as a tabular listing of grid points for each subcase or frequency, depending on the rigid format. SØRT2 is not available.
PRINT	The printer will be the output media.
PUNCH	The card punch will be the output media.
ALL	Multipoint forces of constraint for all points will be output (only nonzero entries).
NØNE	Multipoint forces of constraint for no points will be output.
n	Set identification of previously appearing SET card. Only multipoint constraint forces for points whose identification numbers appear on this SET card will be output (Integer > 0).

Remarks:
1. Both PRINT and PUNCH may be requested.
2. MPCFØRCE = NØNE allows overriding an overall output request.
3. Only valid for statics and real eigenvalue analyses.
4. A request for MPCFØRCE is not allowed for axisymmetric elements.

Case Control Data Card NCHECK - Stress and Element Forces Numerical Accuracy Check

Description: Requests stress and element force numerical accuracy check.

Format and Example(s):

NCHECK [= n]

NCHECK

NCHECK = 6

Option	Meaning
n	A printout of the number of significant digits accuracy is issued for each element having an entry with less than n significant digits in the stress or force calculation.

Remarks:

1. All the elements requested on the STRESS and/or FØRCE card (or their equivalent ELSTRESS and/or ELFØRCE card) are checked.
2. The default for n is five (5) when n is not specified.
3. These checks measure the quality of the computations to obtain element stresses and element forces. They do not measure the quality of the model being analyzed.
4. See Theoretical Manual Section 3.7.2 for a description of the accuracy check.
5. The printout identifies the element types, identification number and the subcase. The entries checked are as follows.

Element Type	Entries
RØD,CØNRØD,TUBE	$F_A, T, \sigma_A, \sigma_T$
BAR	$F_A, T, M_{1a}, M_{1b}, M_{2a}, M_{2b}, V_1, V_2, \sigma_a$
TRMEM,QDMEM,QDMEM1	$\sigma_x, \sigma_y, \tau_{xy}$
TRPLT,QDPLT,TRIA1,TRIA2,QUAD1,QUAD2,TRBSC	$\sigma_{x1}, \sigma_{y1}, \sigma_{xy1}, \sigma_{x2}, \sigma_{y2}, \tau_{xy2}, M_x, M_y, M_{xy}, V_x, V_y$
HEXA1,HEXA2,WEDGE,TETRA	$\sigma_x, \sigma_y, \sigma_z, \tau_{yz}, \tau_{xz}, \tau_{xy}$
SHEAR	$\sigma_{MAX}, \sigma_{AVE}$, corner forces, kick forces, and shears.
TWIST	$\sigma_{MAX}, \sigma_{AVE}, M_{1-3}, M_{2-4}$
QDMEM2	$\sigma_x, \sigma_y, \tau_{xy}$, corner forces, kick forces, and shears.
IHEX1, IHEX2, IHEX3	σ_{NORMAL}, σ_{SHEAR}, and $\sigma_{PRINCIPAL}$ for each direction, grid point, and centroid.

Case Control Data Card NLLØAD - Nonlinear Load Output Request.

Description: Requests form and type of nonlinear load output for Transient problems.

Format and Example(s):

$$\text{NLLØAD } [(\begin{matrix}\text{PRINT}\\\text{PUNCH}\end{matrix})] = \left\{\begin{matrix}\text{ALL}\\ n\\ \text{NØNE}\end{matrix}\right\}$$

NLLØAD = ALL

Option	Meaning
PRINT	The printer will be the output media.
PUNCH	The card punch will be the output media.
ALL	Nonlinear loads for all solution points will be output.
NØNE	Nonlinear loads will not be output.
n	Set identification of previously appearing SET card. (Integer > 0). Only nonlinear loads for points whose identification numbers appear on this SET card will be output.

Remarks:
1. Both PRINT and PUNCH may be used.
2. Nonlinear loads are output only in the solution (D or H) set.
3. The output format will be SØRT2.
4. An output request for ALL in Transient response problems generally produces large amounts of printout. An alternative to this would be to define a SET of interest.
5. THERMAL = NØNE allows overriding an overall output request.

Case Control Data Card NØNLINEAR - Nonlinear Load Set Selection.

Description: Selects nonlinear load for transient problems.

Format and Example(s):

NØNLINEAR = n

NØNLINEAR LØAD SET = 75

Option	Meaning
n	Set identification of NØLINi cards (Integer > 0).

Remarks: NØLINi cards will not be used unless selected in Case Control.

Case Control Data Card ØFRF ... - Output Frequency Set.

Description: Selects from th. .olution set of frequencies a subset for output requests in direct or modal frequency analysis. In flutter analysis, it selects a subset of velocities.

Format and Example(s):

ØFREQUENCY = $\left\{\frac{\text{ALL}}{\text{n}}\right\}$

ØFREQUENCY = ALL

ØFREQUENCY SET = 15

Option	Meaning
ALL	Output for all frequencies will be printed out.
n	Set identification of previously appearing SET card. (Integer > 0). Output for frequencies closest to those given on this SET card will be output.

Remarks:

1. ØFREQUENCY is defaulted to ALL if it is not supplied.
2. In flutter analysis, the selected set lists velocities in input units. If there are n velocities in the list, the n points with velocities closest to those in the list will be selected for output.
3. This card is used in conjunction with the MØDACC module to limit the frequencies for which mode acceleration computations are performed.
4. In Flutter Analysis, the selected set refers to the imaginary part of the complex eigenvalues.

   K or KE method: Velocity (input units)
   PK method: Frequency

5. In Aeroelastic Response (with RLØAD selection), the selected set refers to the frequency (cycles per unit time).

Case Control Data Card ØLØAD - Applied Load Output Request

Description: Requests form and type of applied load vector output.

Format and Example(s):

$$\text{ØLØAD} \quad \left[\left(\frac{\text{SØRT1}}{\text{SØRT2}}, \frac{\text{PRINT}}{\text{PUNCH}}, \frac{\text{REAL}}{\frac{\text{IMAG}}{\text{PHASE}}}\right)\right] = \begin{Bmatrix} \text{ALL} \\ n \\ \text{NØNE} \end{Bmatrix}$$

ØLØAD = ALL

ØLØAD(SØRT1, PHASE) = 5

Option	Meaning
SØRT1	Output will be presented as a tabular listing of grid points for each load, frequency, eigenvalue, or time, depending on the rigid format. SØRT1 is not available in Transient problems (where the default is SØRT2).
SØRT2	Output will be presented as a tabular listing of load, frequency, or time for each grid point. SØRT2 is available only in Static Analysis, Transient and Frequency Response problems.
PRINT	The printer will be the output media.
PUNCH	The card punch will be the output media.
REAL or IMAG	Requests real and imaginary output on Complex Eigenvalue or Frequency Response problems.
PHASE	Requests magnitude and phase ($0.0° \leq$ phase $< 360.0°$) on Complex Eigenvalue or Frequency Response problems.
ALL	Applied loads for all points will be output. (SØRT1 will only output nonzero values).
NØNE	Applied loads for no points will be output.
n	Set identification of previously appearing SET card. Only loads on points whose identification numbers appear on this SET card will be output (Integer > 0).

Remarks:
1. Both PRINT and PUNCH may be requested.
2. An output request for ALL in Transient and Frequency response problems generally produces large amounts of printout. An alternative to this would be to define a SET of interest.
3. In Static Analysis or Frequency Response problems, any request for SØRT2 output causes all output to be SØRT2.
4. A request for SØRT2 causes loads (zero and nonzero) to be output.
5. ØLØAD = NØNE allows overriding an overall output request.

Case Control Data Card ØTIME - Output Time Set

Description: Selects from the solution set of times a subset for output requests.

Format and Example(s):

$$ØTIME = \left\{ \begin{array}{c} \underline{ALL} \\ n \end{array} \right\}$$

ØTIME = ALL

ØTIME = 15

Option	Meaning
ALL	Output for all times will be printed out.
n	Set identification of previously appearing SET card. (Integer > 0). Output for times closest to those given on this SET card will be output.

Remarks:

1. ØTIME is defaulted to ALL if it is not supplied.
2. The ØTIME card is particularly useful for restarts to request a subset of the output (i.e., stresses at only peak times, etc.).
3. This card can be used in conjunction with the MØDACC module to limit the times for which mode acceleration computations are performed.

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Case Control Data Card ØUTPUT - Output Packet Delimiter.

Description: Delimits the various output packets, structure plotter, curve plotter, and printer/punch.

Format and Example(s):

$$ØUTPUT \left[\begin{pmatrix} PLØT \\ XYØUT \\ XYPLØT \end{pmatrix}\right]$$

ØUTPUT

ØUTPUT(PLØT)

ØUTPUT(XYØUT)

Option	Meaning
No qualifier	Beginning of printer output packet - this is not a required card.
PLØT	Beginning of structure plotter packet. This card must preceed all structure plotter control cards.
XYØUT or XYPLØT	Beginning of curve plotter packet. This card must precede all curve plotter control cards. XYPLØT and XYØUT are entirely equivalent.

Remarks:

1. The structure plotter packet and the curve plotter packet must be at the end of the Case Control Deck. Either may come first.

2. The delimiting of a printer packet is completely optional.

Case Control Data Card PLCØEFFICIENT - Piecewise Linear Coefficient Set.

Description: Selects the coefficient set for Piecewise Linear problems.

Format and Example(s):

PLCØEFFICIENT = n

PLCØEFFICIENT = 25

Option	Meaning
n	Set identification of PLFACT card (Integer > 0).

Remarks: 1. PLFACT cards will not be used unless selected.

Case Control Data Card PLØTID - Plotter Identification.

Description: Defines BCD identification which will appear on the first frame of any NASTRAN plotter output.

Format and Example(s):

PLØTID = { Any BCD data }

PLØTID = RETURN TØ B.J. SMITH, RØØM 201, BLDG 85, ABC CØMPANY

Remarks:

1. PLØTID must appear before any ØUTPUT(PLØT), ØUTPUT(XYØUT) or ØUTPUT(XYPLØT) cards.
2. The presence of PLØTID causes a special header frame to be plotted with the supplied identification plotted several times. This allows for easy identification of the NASTRAN plotter output.
3. If no PLØTID card appears, no ID frame will be plotted.
4. The PLØTID header frame will not be generated for the table plotters.

Case Control Data Card PRESSURE - Hydroelastic Pressure Output Request.

Description: Requests form and type of displacement and hydroelastic pressure vector output.

Format and Example(s):

$$\text{PRESSURE}\left[\left(\frac{\text{SØRT1}}{\text{SØRT2}}, \frac{\text{PRINT}}{\text{PUNCH}}, \frac{\text{REAL}}{\frac{\text{IMAG}}{\text{PHASE}}}\right)\right] = \left\{\begin{matrix}\text{ALL}\\ n\\ \text{NØNE}\end{matrix}\right\}$$

PRESSURE = 5

PRESSURE(IMAG) = ALL

PRESSURE(SØRT2, PUNCH, REAL) = ALL

Option	Meaning
SØRT1	Output will be presented as a tabular listing of grid points for each load, frequency, eigenvalue, or time, depending on the rigid format. SØRT1 is not available in Transient problems problems (where the default is SØRT2).
SØRT2	Output will be presented as a tabular listing of frequency or time for each grid point. SØRT2 is available only in Transient and Frequency Response problems.
PRINT	The printer will be the output media.
PUNCH	The card punch will be the output media.
REAL or IMAG	Requests real and imaginary output on Complex Eigenvalue or Frequency Response problems.
PHASE	Requests magnitude and phase ($0.0° \leq$ phase $< 360.0°$) on Complex Eigenvalue or Frequency Response problems.
ALL	Displacements and pressures for all points will be output.
NØNE	Displacements and pressures for no points will be output.
n	Set identification of previously appearing SET card. Only displacements and pressures of points whose identification numbers appear on this SET card will be output (Integer > 0).

Remarks:

1. Both PRINT and PUNCH may be requested.
2. An output request for ALL in Transient and Frequency response problems generally produces large amounts of printout. An alternative to this would be to define a SET of interest.
3. In a Frequency Response problem any request for SØRT2 causes all output to be SØRT2.
4. DISPLACEMENT and VECTØR are alternate forms and are entirely equivelent to PRESSURE.
5. PRESSURE = NØNE allows overriding an overall output request.

Case Control Data Card <u>RANDØM</u> - Random Analysis Set Selection

<u>Description</u>: Selects the RANDPS and RANDTi cards to be used in Random Analysis.

<u>Format and Example(s)</u>:

RANDØM = n
RANDØM = 177

Option	Meaning
n	Set identification of RANDPS and RANDTi cards to be used in RANDØM analysis (Integer > 0).

<u>Remarks</u>:

1. RANDPS cards must be selected to do Random Analysis.
2. RANDPS must be selected in the first subcase of the current loop. RANDPS may not reference subcases in a different loop.

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Case Control Data Card REPCASE - Repeat Case Subcase Delimiter.

Description: Delimits and identifies a repeated subcase.

Format and Example(s):

REPCASE n

REPCASE 137

Option	Meaning
n	Subcase number (Integer > 1).

Remarks:

1. "n" must be strictly increasing (i.e. greater than all previous subcase set identification numbers).
2. This case will only re-output the previous real case. This allows additional set specification.
3. REPCASE may only be used in Statics or Inertia Relief.
4. One or more repeated subcases (REPCASEs) must immediately follow the subcase (SUBCASE) to which they refer. (See example 4 in Section 2.3.3).

Case Control Data Card SACCELERATIØN - Solution Set Acceleration Output Request

Description: Requests form and type of solution set acceleration output.

Format and Example(s):

$$\text{SACCELERATIØN}\left[\left(\begin{matrix}\text{SØRT1}\\ \text{SØRT2}\end{matrix},\ \begin{matrix}\text{PRINT}\\ \text{PUNCH}\end{matrix},\ \begin{matrix}\text{REAL}\\ \text{IMAG}\\ \text{PHASE}\end{matrix}\right)\right] = \left\{\begin{matrix}\text{ALL}\\ \text{n}\\ \text{NØNE}\end{matrix}\right\}$$

SACCELERATIØN = ALL

SACCELERATIØN(PUNCH, IMAG) = 142

Option	Meaning
SØRT1	Output will be presented as a tabular listing of grid points for each load, frequency, eigenvalue, or time, depending on the rigid format. SØRT1 is not available in Transient problems (where the default is SØRT2).
SØRT2	Output will be presented as a tabular listing of frequency or time for each grid point (or mode number). SØRT2 is available only in Transient and Frequency Response problems.
PRINT	The printer will be the output media.
PUNCH	The card punch will be the output media.
REAL or IMAG	Requests real and imaginary output on Frequency Response problems.
PHASE	Requests magnitude and phase ($0.0° \le$ phase $< 360.0°$) on Frequency Response problems.
ALL	Acceleration for all solution points (modes) will be output.
NØNE	Acceleration for no solution points (modes) will be output.
n	Set identification of a previously appearing SET card. Only accelerations of points whose identification numbers appear on this SET card will be output (Integer > 0)

Remarks:

1. Both PRINT and PUNCH may be requested.
2. An output request for ALL in Transient and Frequency response problems generally produces large amounts of printout. An alternative to this would be to define a SET of interest.
3. Acceleration output is only available for Transient and Frequency Response problems.
4. In a Frequency Response problem any request for SØRT2 output causes all output to be SØRT2.
5. SACCELERATION = NØNE allows overriding an overall output request.

Case Control Data Card SDAMPING - Structural Damping.

Description: Selects table which defines damping as a function of frequency in Modal Formulation problems.

Format and Example(s):

SDAMPING = n

SDAMPING = 77

Option	Meaning
n	Set identification of a TABDMP1 table (Integer > 0).

Remarks: If SDAMPING is not used BHH = [0].

Case Control Data Card <u>SDISPLACEMENT</u> - Solution Set Displacement Output Request.

Description: Requests form and type of solution set displacement output.

Format and Example(s):

$$\text{SDISPLACEMENT}\left[\left(\frac{\text{SØRT1}}{\text{SØRT2}},\ \frac{\text{PRINT}}{\text{PUNCH}},\ \frac{\text{REAL}}{\begin{matrix}\text{IMAG}\\ \text{PHASE}\end{matrix}}\right)\right] = \left\{\begin{matrix}\text{ALL}\\ \text{n}\\ \text{NØNE}\end{matrix}\right\}$$

SDISPLACEMENT = ALL

SDISPLACEMENT(SØRT2, PUNCH, PHASE) = NØNE

Option	Meaning
SØRT1	Output will be presented as a tabular listing of grid points for each load, frequency, eigenvalue, or time, depending on the rigid format. SØRT1 is not available in Transient problems (where the default is SØRT2).
SØRT2	Output will be presented as a tabular listing of frequency or time for each grid point (or mode number). SØRT2 is available only in Transient and Frequency Response problems.
PRINT	The printer will be the output media.
PUNCH	The card punch will be the output media.
REAL or IMAG	Requests real and imaginary output on Complex Eigenvalue or Frequency Response problems.
PHASE	Requests magnitude and phase ($0.0° \leq$ phase $< 360.0°$) on Complex Eigenvalue or Frequency Response problems.
ALL	Displacements for all points (modes) will be output.
NØNE	Displacements for no points (modes) will be output.
n	Set identification of previously appearing SET card. Only displacements of points whose identification numbers appear on this SET card will be output (Integer > 0).

Remarks:
1. Both PRINT and PUNCH may be requested.
2. An output request for ALL in Transient and Frequency response problems generally produces large amounts of printout. An alternative to this would be to define a SET of interest.
3. In a Frequency Response problem any request for SØRT2 causes all output to be SØRT2.
4. SVECTØR is an alternate form which is entirely equivalent to SDISPLACEMENT.
5. SDISPLACEMENT = NØNE allows overriding an overall output request.

Case Control Data Card SET - Set Definition Card.

Description: 1) Lists identification numbers (point or element) for output requests.
2) Lists the frequencies for which output will be printed in Frequency Response Problems.

Format and Example(s):

1) SET n = $\{i_1[,i_2, i_3$ THRU i_4 EXCEPT i_5, i_6, i_7, i_8 THRU $i_9]\}$

SET 77 = 5

SET 88 = 5, 6, 7, 8, 9, 10 THRU 55 EXCEPT 15, 16, 77,
78, 79, 100 THRU 300

SET 99 = 1 THRU 100000

2) SET n = $\{r_1 [, r_2, r_3, r_4]\}$

SET 101 = 1.0, 2.0, 3.0

SET 105 = 1.009, 10.2, 13.4,
14.0, 15.0

Option	Meaning
n	Set identification (Integer > 0). Any set may be redefined by reassigning its identification number. Sets inside SUBCASE delimiters are local to the SUBCASE.
i_1, i_2 etc.	Element or point identification number at which output is requested. (Integer > 0) If no such identification number exists, the request is ignored.
i_3 THRU i_4	Output at set identification numbers i_3 thru i_4 ($i_4 > i_3$).
EXCEPT	Set identification numbers following EXCEPT will be deleted from output list as long as they are in the range of the set defined by the immediately preceding THRU.
r_1, r_2 etc.	Frequencies for output (Real $\geq$ 0.0). The nearest solution frequency will be output. EXCEPT and THRU cannot be used.

Remarks:

1. A SET card may be more than one physical card. A comma (,) at the end of a physical card signifies a continuation card. Commas may not end a set.

2. Identification numbers following EXCEPT within the range of the THRU must be in ascending order.

3. In the first format, i_8 must be greater than i_4, i.e., the THRU must not be within an EXCEPT range.

Case Control Data Card SPC - Single-Point Constraint Set Selection.

Description: Selects the single-point constraint set to be applied to the structural model.

Format and Example(s):

SPC = n

SPC = 10

Option	Meaning
n	Set identification of a single-point constraint set and hence must appear on an SPC, SPC1, SPCADD, SPCAX, SPCS, or SPCS1 card (Integer > 0).

Remarks: SPC, SPC1, SPCADD, SPCAX, SPCS, or SPCS1 cards will not be used by NASTRAN unless selected in Case Control.

Case Control Data Card <u>SPCFØRCES</u> - Single-Point Forces of Constraint Output Request.

<u>Description</u>: Requests form and type of Single-Point Force of constraint vector output.

<u>Format and Example(s)</u>:

$$\text{SPCFØRCES} \quad \left[\left(\begin{array}{c}\underline{\text{SØRT1}}\\ \text{SØRT2}\end{array}, \begin{array}{c}\underline{\text{PRINT}}\\ \text{PUNCH}\end{array}, \begin{array}{c}\underline{\text{REAL}}\\ \text{IMAG}\\ \text{PHASE}\end{array}\right)\right] = \left\{\begin{array}{c}\text{ALL}\\ n\\ \text{NØNE}\end{array}\right\}$$

SPCFØRCES = 5

SPCFØRCES(SØRT2, PUNCH, PRINT, IMAG) = ALL

SPCFØRCES(PHASE) = NØNE

<u>Option</u>	<u>Meaning</u>
SØRT1	Output will be presented as a tabular listing of grid points for each load, frequency, eigenvalue, or time, depending on the rigid format. SØRT1 is not available in Transient problems (where the default is SØRT2).
SØRT2	Output will be presented as a tabular listing of load, frequency, or time for each grid point. SØRT2 is available only in Static Analysis, Transient and Frequency Response problems.
PRINT	The printer will be the output media.
PUNCH	The card punch will be the output media.
REAL or IMAG	Requests real and imaginary output on Complex Eigenvalue or Frequency Response problems.
PHASE	Requests magnitude and phase ($0.0° \leq$ phase $< 360.0°$) on Complex Eigenvalue or Frequency Response problems.
ALL	Single-Point forces of constraint for all points will be output. (SØRT1 will only output nonzero values.)
NØNE	Single point forces of constraint for no points will be output.
n	Set identification of previously appearing SET card. Only single-point forces of constraint for points whose identification numbers appear on this SET card will be output (Integer > 0).

<u>Remarks</u>:

1. Both PRINT and PUNCH may be requested.
2. An output request for ALL in Transient and Frequency response problems generally produces large amounts of printout. An alternative to this would be to define a SET of interest.
3. In Static Analysis or Frequency Response problems, any request for SØRT2 output causes all output to be SØRT2.
4. A request for SØRT2 causes loads (zero and nonzero) to be output.
5. SPCFØRCES = NØNE allows overriding an overall output request.
6. In heat transfer analysis, SPCFØRCE output is the power necessary to maintain a grid point at a fixed temperature.

Case Control Data Card <u>STRAIN</u> - Element Strain/Curvature Output Request

<u>Description</u>: Requests element strain/curvature output.

<u>Format and Example(s)</u>:

$$\text{STRAIN} \left[\left(\begin{matrix}\text{PRINT}\\ \text{PUNCH}\end{matrix}\right)\right] = \left\{\begin{matrix}\text{ALL}\\ \text{n}\\ \text{NØNE}\end{matrix}\right\}$$

STRAIN (PUNCH) = 5

STRAIN (PRINT,PUNCH) = ALL

Option	Meaning
PRINT	The printer will be the output media.
PUNCH	The card punch will be the output mdeia.
ALL	Strains/curvatures for all elements will be output. See Remark 5.
NØNE	Strains/curvatures for no elements will be output.
n	Set identification of previously appearing SET card (Integer > 0). Only strains/curvatures for elements whose identification numbers appear on this SET card will be output. See Remark 5.

<u>Remarks</u>:

1. Element strains/curvatures are output from Static Analysis (Rigid Format 1) only.
2. The output will be in SØRT1 format.
3. Both PRINT and PUNCH may be requested.
4. STRAIN = NØNE allows overriding an overall output request.
5. Strains/curvatures are computed only for TRIA1, TRIA2, QUAD1, and QUAD2 elements.
6. If element strains/curvatures in material coordinate system are desired, the parameter STRAIN (see the description of the PARAM bulk data card in Section 2.4.2) should be set to be a positive integer. If, in addition to element strains/curvatures in material coordinate system, strains/curvatures at the connected grid points are also desired, the parameter STRAIN should be set to 0.

Case Control Data Card STRESS - Element Stress Output Request.

Description: Requests form and type of element stress output.

Format and Example(s):

$$\text{STRESS} \quad \left[\left(\frac{\text{SØRT1}}{\text{SØRT2}}, \frac{\text{PRINT}}{\text{PUNCH}}, \frac{\text{REAL}}{\begin{matrix}\text{IMAG}\\ \text{PHASE}\end{matrix}}\right)\right] = \left\{\begin{matrix}\text{ALL}\\ n\\ \text{NØNE}\end{matrix}\right\}$$

STRESS = 5

STRESS = ALL

STRESS(SØRT1, PRINT, PUNCH, PHASE) = 15

Option	Meaning
SØRT1	Output will be presented as a tabular listing of elements for each load, frequency, eigenvalue, or time, depending on the rigid format. SØRT1 is not available in Transient problems (where the default is SØRT2).
SØRT2	Output will be presented as a tabular listing of load, frequency, or time for each element type. SØRT2 is available only in Static Analysis, Transient and Frequency Response problems.
PRINT	The printer will be the output media.
PUNCH	The card punch will be the output media.
REAL or IMAG	Requests real and imaginary printout on Complex Eigenvalue or Frequency Response problems.
PHASE	Requests magnitude and phase (0.0° ≤ phase < 360.0°) on Complex Eigenvalue or Frequency Response problems.
ALL	Stresses for all elements will be output.
n	Set identification of a previously appearing SET card (Integer > 0). Only stresses for elements whose identification numbers appear on this SET card will be output.
NØNE	Stresses for no points will be output.

Remarks:

1. Both PRINT and PUNCH may be requested.
2. An output request for ALL in Transient and Frequency response problems generally produces large amounts of printout. An alternative to this would be to define a SET of interest.
3. In Static Analysis or Frequency Response problems, any request for SØRT2 output causes all output to be SØRT2.
4. ELSTRESS is an alternate form and is entirely equivalent to STRESS.
5. STRESS = NØNE allows overriding an overall output request.
6. If element stresses in material coordinate system are desired (only for TRIA1, TRIA2, QUAD1 and QUAD2 elements and only in Rigid Format 1), the parameter STRESS (see the description of the PARAM bulk data card in Section 2.4.2) should be set to be a positive integer. If, in addition to element stresses in material coordinate system, stresses at the connected grid points are also desired, the parameter STRESS should be set to 0.

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Case Control Data Card <u>SUBCASE</u> - Subcase Delimiter.

<u>Description</u>: Delimits and identifies a subcase.

<u>Format and Example(s)</u>:

SUBCASE n
SUBCASE 101

Option	Meaning
n	Subcase identification number (Integer > 0).

<u>Remarks</u>:

1. The subcase identification number, n, must be strictly increasing (i.e., greater than all previous subcase identification numbers).
2. Plot requests and RANDØM requests refer to n.

Case Control Data Card SUBCØM - Combination Subcase Delimiter.

Description: Delimits and identifies a combination subcase.

Format and Example(s):

SUBCØM n

SUBCØM 125

Option	Meaning
n	Subcase identification number (Integer > 2).

Remarks:

1. The subcase identification number, n, must be strictly increasing (i.e., greater than all previous subcase identification numbers).
2. A SUBSEQ card may appear in this subcase.
3. SUBCØM may only be used in Statics or Inertia Relief problems.
4. Output requests above the subcase level will be utilized.

Case Control Data Card <u>SUBSEQ</u> - Subcase Sequence Coefficients.

Description: Gives the coefficients for forming a linear combination of the previous subcases.

Format and Example(s):

SUBSEQ = R_1 [, R_2, R_3, . . ., R_N]
SUBSEQ = 1.0, -1.0, 0.0, 2.0

Option	Meaning
R_1 to R_N	Coefficients of the previously occuring subcases (Real).

Remarks:

1. A SUBSEQ card must only appear in a SUBCØM subcase.
2. A SUBSEQ card may be more than one physical card. A comma at the end signifies a continuation card.
3. SUBSEQ may only be used in Statics or Inertia Relief problems.
4. A default value of 1.0 is used for all of the coefficients if no SUBSEQ card is used.

Case Control Data Card <u>SUBTITLE</u> - Output Subtitle.

<u>Description</u>: Defines a BCD subtitle which will appear on the second heading line of each page of NASTRAN printer output.

<u>Format and Example(s)</u>:

SUBTITLE = { Any BCD data }

SUBTITLE = NASTRAN PRØBLEM NØ. 5-1A

<u>Remarks</u>:

1. SUBTITLE appearing at the subcase level will title output for that subcase only.
2. SUBTITLE appearing before all subcases will title any outputs which are not subcase dependent.
3. If no SUBTITLE card is supplied, the subtitle line will be blank.
4. SUBTITLE information is also placed on NASTRAN plotter output as applicable.

Case Control Data Card SVECTØR - Solution Set Displacement Output Request.

Description: Requests form and type of solution set displacement output.

Format and Example(s):

$$\text{SVECTØR} \quad \left[\left(\frac{\text{SØRT1}}{\text{SØRT2}}, \frac{\text{PRINT}}{\text{PUNCH}}, \frac{\text{REAL}}{\substack{\text{IMAG}\\ \text{PHASE}}}\right)\right] = \left\{\begin{matrix}\text{ALL}\\ \text{n}\\ \text{NØNE}\end{matrix}\right\}$$

SVECTØR = ALL

SVECTØR(SØRT2, PUNCH, PHASE) = NØNE

Option	Meaning
SØRT1	Output will be presented as a tabular listing of grid points for each load, frequency, eigenvalue, or time, depending on the rigid format. SØRT1 is not available in Transient problems (where the default is SØRT2).
SØRT2	Output will be presented as a tabular listing of frequency or time for each grid point (or mode number). SØRT2 is available only in Transient and Frequency Response problems.
PRINT	The printer will be the output media.
PUNCH	The card punch will be the output media.
REAL or IMAG	Requests real and imaginary output on Complex Eigenvalue or Frequency Response problems.
PHASE	Requests magnitude and phase ($0.0° \leq$ phase $< 360.0°$) on Complex Eigenvalue or Frequency Response problems.
ALL	Displacements for all points (modes) will be output.
NØNE	Displacements for no points (modes) will be output.
n	Set identification of previously appearing SET card. Only displacements of points whose identification numbers appear on this SET card will be output (Integer > 0).

Remarks:
1. Both PRINT and PUNCH may be requested.
2. An output request for ALL in Transient and Frequency response problems generally produces large amounts of printout. An alternative to this would be to define a SET of interest.
3. In a frequency response problem any request for SØRT2 causes all output to be SØRT2.
4. SDISPLACEMENT is an alternate form and is entirely equivalent to SVECTØR.
5. SVECTØR = NØNE allows overriding an overall output request.

Case Control Data Card <u>SVELØCITY</u> - Solution Set Velocity Output Request

Description: Requests form and type of solution set velocity output.

Format and Example(s):

$$\text{SVEL\O CITY}\left[\left(\frac{\text{S\O RT1}}{\text{S\O RT2}}, \frac{\text{PRINT}}{\text{PUNCH}}, \frac{\text{REAL}}{\frac{\text{IMAG}}{\text{PHASE}}}\right)\right] = \begin{Bmatrix}\text{ALL} \\ n \\ \text{N\O NE}\end{Bmatrix}$$

SVELØCITY = 5

SVELØCITY(SØRT2, PUNCH, PRINT, PHASE) = ALL

Option	Meaning
SØRT1	Output will be presented as a tabular listing of grid points for each load, frequency, eigenvalue, or time, depending on the rigid format. SØRT1 is not available in Transient problems (where the default is SØRT2).
SØRT2	Output will be presented as a tabular listing of frequency or time for each grid point (or mode number). SØRT2 is available only in Transient and Frequency Response problems.
PRINT	The printer will be the output media.
PUNCH	The card punch will be the output media.
REAL or IMAG	Requests real and imaginary output on Frequency Response problems.
PHASE	Requests magnitude and phase ($0.0° \le$ phase $< 360.0°$) on Frequency Response problems.
ALL	Velocity for all solution points (modes) will be output.
NØNE	Velocity for no solution points (modes) will be output.
n	Set identification of a previously appearing SET card. Only velocities of points whose identification numbers appear on this SET card will be output (Integer > 0).

Remarks:
1. Both PRINT and PUNCH may be requested.
2. An output request for ALL in Transient and Frequency response problems generally produces large amounts of printout. An alternative to this would be to define a SET of interest.
3. Velocity output is only available for Transient and Frequency Response problems.
4. In a Frequency Response problem any request for SØRT2 output causes all output to be SØRT2.
5. SVELØCITY = NØNE allows overriding an overall output request.

Case Control Data Card SYM - Symmetry Subcase Delimiter.

Description: Delimits and identifies a symmetry subcase.

Format and Example(s):

SYM n

SYM 123

Option	Meaning
n	Subcase identification number (Integer > 0).

Remarks:
1. The subcase identification number, n, must be strictly increasing (i.e., greater than all previous subcase identification numbers).
2. Plot requests and RANDØM requests should refer to n.
3. Overall output requests will not propagate into a SYM subcase (i.e. any output desired must be requested within the subcase).
4. SYM may only be used in Statics or Inertia Relief.

Case Control Data Card SYMCØM - Symmetry Combination Subcase Delimiter.

Description: Delimits and identifies a symmetry combination subcase.

Format and Example(s):

SYMCØM n

SYMCØM 123

Option	Meaning
n	Subcase identification number (Integer > 2).

Remarks: 1. The subcase identification number, n, must be strictly increasing (i.e., greater than all previous subcase identification numbers).

2. SYMCØM may only be used in Statics or Inertia Relief problems.

Case Control Data Card SYMSEQ - Symmetry Sequence Coefficients.

Description: Gives the coefficients for combining the symmetry subcases into the total structure.

Format and Example(s):

SYMSEQ = R_1[, R_2, R_3 --- R_n]
SYMSEQ = 1.0, -2.0, 3.0, 4.0

Option	Meaning
R_1 to R_N	Coefficients of the previously occurring N SYM subcases (Real).

Remarks:

1. A SYMSEQ card may only appear in a SYMCØM subcase.
2. The default value for the coefficients is 1.0 if no SYMSEQ card appears.
3. A SYMSEQ card may consist of more than one physical card.
4. SYMSEQ may only be used in Statics or Inertia Relief.

Case Control Data Card TEMPERATURE - Thermal Properties Set Selection.

Description: Selects the temperature set to be used in either material property calculation or thermal loading.

Format and Example(s):

$$\text{TEMPERATURE}\left[\begin{pmatrix}\text{MATERIAL}\\ \text{LØAD}\\ \underline{\text{BØTH}}\end{pmatrix}\right] = n$$

TEMPERATURE(LØAD) = 15

TEMPERATURE(MATERIAL) = 7

TEMPERATURE = 7

Option	Meaning
MATERIAL	The selected temperature table will be used to determine temperature-dependent material properties indicated on the MATTi type cards.
LØAD	The selected temperature table will be used to determine an equivalent static load.
BØTH	Both options, MATERIAL and LØAD will use the same temperature table.
n	Set identification number of TEMP, TEMPD, TEMPP1, TEMPP2, TEMPP3, TEMPRB, or TEMPAX cards (Integer > 0).

Remarks:

1. Only one temperature-dependent material request may be made in any problem and must be above the subcase level.
2. Thermal loading may only be used in Statics, Inertia Relief, Differential Stiffness, and Buckling problems.
3. Temperature-dependent materials may not be used in Piecewise Linear problems.
4. The total load applied will be the sum of external (LØAD), thermal (TEMP(LØAD)), element deformation (DEFØRM) and constrained displacement (SPC) loads.
5. Static, thermal and element deformation loads should have unique set identification numbers.
6. In heat transfer analysis, the TEMP data is used for the following special purposes:
   a) The Case Control card TEMP(MATERIAL) will select the initial estimated temperature field for nonlinear conductivity and radiation effects. See Section 1.8 (APP HEAT, Rigid Formats 1, 3, and 9).
   b) In Rigid Format 3, heat boundary temperatures are defined by the specified Case Control card TEMP(MATERIAL). These points are specified with SPC data.

Case Control Data Card TFL - Transfer Function Set Selection.

Description: Selects the Transfer function set to be added to the direct input matrices.

Format and Example(s):

TFL = n

TFL = 77

Option	Meaning
n	Set identification of a TF card (Integer > 0).

Remarks: 1. Transfer functions will not be used unless selected in the Case Control Deck.

2. Transfer functions are supported on dynamics problems only.

3. Transfer functions are simply another form of direct matrix input.

Case Control Data Card THERMAL - Temperature Output Request.

Description: Requests form and type of temperature vector output.

Format and Example(s):

$$\text{THERMAL} \begin{bmatrix} \frac{\text{PRINT}}{\text{PUNCH}} , \begin{matrix}\text{SØRT1} \\ \text{SØRT2}\end{matrix} \end{bmatrix} = \begin{Bmatrix} \text{ALL} \\ \text{n} \\ \text{NØNE} \end{Bmatrix}$$

THERMAL = 5

THER(PRINT,PUNCH) = ALL

Option	Meaning
PRINT	The printer will be the output media.
PUNCH	The card punch will be the output media.
ALL	Temperatures for all points will be output.
NØNE	Temperatures for no points will be output.
n	Set identification of previously appearing SET card. Only temperatures of points whose identification numbers appear on this SET card will be output (Integer > 0).

Remarks:

1. Both PRINT and PUNCH may be requested. The punched output will consist of double field TEMP* Bulk Data cards defining the temperatures at the grid points.

2. THERMAL output request is designed for use with the Heat Transfer option. The printed output will have temperature headings and the punched output will be TEMP bulk data cards. The SID on a bulk data card will be the subcase number (= 1 if no defined subcases). The output format will be SØRT1 for Static problems and SØRT2 for Transient problems.

3. An output request for ALL in Transient response problems generally produces large amounts of printout. An alternative to this would be to define a SET of interest.

4. DISPLACEMENT and VECTØR are alternate forms and are entirely equivalent to THERMAL.

5. THERMAL = NØNE allows overriding an overall output request.

6. The output format will be SØRT1 for Rigid Formats 1 and 3; SØRT2 for Rigid Format 9.

7. If punched output is desired in Rigid Format 9 for subsequent use in the other Rigid Formats, SØRT1 format must be selected.

Case Control Data Card TITLE - Output Title.

Description: Defines a BCD title which will appear on the first heading line of each page of NASTRAN printer output.

Format and Example(s):

TITLE = { Any BCD data }

TITLE = **$// ABCDEFGHI .... $

Remarks:
1. TITLE appearing at the subcase level will title output for that subcase only.
2. TITLE appearing before all subcases will title any outputs which are not subcase dependent.
3. If no TITLE card is supplied, the title line will contain data and page numbers only.
4. TITLE information is also placed on NASTRAN plotter output as applicable.

Case Control Data Card TSTEP - Transient Time Step Set Selection.

Description: Selects integration and output time steps for Transient problems.

Format and Example(s):

TSTEP = n

TSTEP = 731

Option	Meaning
n	Set identification of a selected TSTEP bulk data card (Integer > 0).

Remarks:
1. A TSTEP card must be selected to execute a Transient problem.
2. Only one TSTEP card may have this value of n.

Case Control Data Card VECTØR - Displacement Output Request.

Description: Requests form and type of displacement vector output.

Format and Example(s):

$$\text{VECTØR} \quad \left[\left(\frac{\underline{\text{SØRT1}}}{\text{SØRT2}}, \frac{\underline{\text{PRINT}}}{\text{PUNCH}}, \begin{matrix} \underline{\text{REAL}} \\ \text{IMAG} \\ \text{PHASE} \end{matrix} \right) \right] = \begin{Bmatrix} \text{ALL} \\ n \\ \text{NØNE} \end{Bmatrix}$$

VECTØR = 5

VECTØR(REAL) = ALL

VECTØR(SØRT2, PUNCH, REAL) = ALL

Option	Meaning
SØRT1	Output will be presented as a tabular listing of grid points for each load, frequency, eigenvalue, or time, depending on the rigid format. SØRT1 is not available on Transient problems (where the default is SØRT2).
SØRT2	Output will be presented as a tabular listing of frequency or time for each grid point. SØRT2 is available only in Transient and Frequency Response problems.
PRINT	The printer will be the output media.
PUNCH	The card punch will be the output media.
REAL or IMAG	Requests real and imaginary output on Complex Eigenvalue or Frequency Response problems.
PHASE	Requests magnitude and phase ($0.0° \leq$ phase $< 360.0°$) on Complex Eigenvalue or Frequency Response problems.
ALL	Displacements for all points will be output.
NØNE	Displacements for no points will be output.
n	Set identification of a previously appearing SET card. Only displacements of points whose identification numbers appear on this SET card will be output (Integer > 0).

Remarks:

1. Both PRINT and PUNCH may be requested.
2. On a Frequency Response problem any request for SØRT2 causes all output to be SØRT2.
3. DISPLACEMENT and PRESSURE are alternate forms and are entirely equivalent to VECTØR.
4. VECTØR = NØNE allows overriding an overall output request.

Case Control Data Card <u>VELØCITY</u> - Velocity Output Request.

<u>Description</u>: Requests form and type of velocity vector output.

<u>Format and Example(s)</u>:

$$\text{VEL\O CITY}\qquad \left[\left(\begin{array}{c}\underline{\text{S\O RT1}}\\ \text{S\O RT2}\end{array},\ \begin{array}{c}\underline{\text{PRINT}}\\ \text{PUNCH}\end{array},\ \begin{array}{c}\underline{\text{REAL}}\\ \text{IMAG}\\ \text{PHASE}\end{array}\right)\right] = \left\{\begin{array}{c}\text{ALL}\\ n\\ \text{N\O NE}\end{array}\right\}$$

VELØCITY = 5

VELØCITY(SØRT2, PHASE, PUNCH) = ALL

Option	Meaning
SØRT1	Output will be presented as a tabular listing of grid points for each load, frequency, eigenvalue, or time, depending on the rigid format. SØRT1 is not available in Transient problems (where the default is SØRT2).
SØRT2	Output will be presented as a tabular listing of frequency or time for each grid point. SØRT2 is available only in Transient and Frequency Response problems.
PRINT	The printer will be the output media.
PUNCH	The card punch will be the output media.
REAL or IMAG	Requests real and imaginary output on Frequency Response problems.
PHASE	Requests magnitude and phase ($0.0° \le$ phase $< 360.0°$) on Frequency Response problems.
ALL	Velocity for all solution points will be ouptut.
NØNE	Velocity for no solution points will be output.
n	Set identification of a previously appearing SET card. Only velocities of points whose identification numbers appear on this SET card will be output (Integer > 0).

<u>Remarks</u>:

1. Both PRINT and PUNCH may be requested.
2. An output request for ALL in Transient and Frequency response problems generally produces large amounts of printout. An alternative to this would be to define a SET of interest.
3. Velocity output is only available for Transient and Frequency Response problems.
4. In a Frequency Response problem any request for SØRT2 output causes all output to be SØRT2.
5. VELØCITY = NØNE allows overriding an overall output request.

Case Control Data Card $ - Comment Card.

Description: Defines a comment card by specifying a $ in column one with commentary text appearing in columns 2-80.

Format and Example(s):

$ {Any BCD data}
$---THIS IS AN EXAMPLE OF A COMMENT CARD.

Remarks: Unlike other Case Control cards which are free field, the comment card must have the $ in column 1.

2.4 BULK DATA DECK

The primary NASTRAN input medium is the Bulk Data card. These cards are used to define the structural model and various pools of data which may be selected by Case Control at execution time.

For large problems the Bulk Data Deck may consist of several thousand cards. In order to minimize the handling of large numbers of cards, provision has been made in NASTRAN to store the bulk data on the Problem Tape, from which it may be modified on subsequent runs. A User's Master File (Section 2.5) is also provided for the storage of Bulk Data Decks.

For any cold start, the entire Bulk Data Deck must be submitted. Thereafter, if the original run was checkpointed, the Bulk Data Deck exists on the Problem Tape in sorted form where it may be modified and reused on restart. On restart the bulk data cards contained in the Bulk Data Deck are added to the bulk data contained on the Old Problem Tape. Cards are removed from the Old Problem Tape (or the User's Master File) by the use of a delete card. Cards to be deleted are indicated by inserting a bulk data card with a / in column one and the sorted bulk data sequence numbers in fields two and three. All bulk data cards in the range of the sequence numbers in fields two and three will be deleted. In the case where only a single card is deleted, field three may be left blank.

The Bulk Data Deck may be submitted with the cards in any order as a sort is performed prior to the execution of the Input File Processor. It should be noted that the machine time to perform this is minimized for a deck that is already sorted. The sort time for a badly sorted deck will become significant for large decks. The user may obtain a printed copy of either the unsorted or sorted bulk data by selection in the Case Control Deck. A sorted echo is necessary in order to make modifications on a secondary execution using the Problem Tape. This echo is automatically provided unless specifically suppressed by the user.

2.4.1 Format of Bulk Data Cards

The bulk data card format is variable to the extent that any quantity except the mnemonic can be punched anywhere within a specified 8 or 16-column field. The normal card uses an 8-column field as indicated in the following diagram:

Small Field Bulk Data Card

1a	2	3	4	5	6	7	8	9	10a
8	8	8	8	8	8	8	8	8	8

The mnemonic is punched in field 1. Fields 2-9 are for data items. The only limitations on data items are that they must lie completely within the designated field, have no imbedded blanks, and must be of the proper type, i.e., blank, integer, real, double precision, or BCD*. All real numbers, including zero, must contain a decimal point. A blank will be interpreted as a real zero or integer zero as required. Real numbers may be encoded in various ways. For example, the real number 7.0 may be encoded as 7.0, .7E1, 0.7+1, 70.-1, .70+1, etc. A double precision number must contain both a decimal point and an exponent with the character D such as 7.0D0. Double precision data values are only allowed in a few situations, such as on the PARAM card. BCD data values consist of one to eight alphanumeric characters, the first of which must be alphabetic.

Normally field 10 is reserved for optional user identification. However, in the case of continuation cards field 10 (except column 73 which is not referenced) is used in conjunction with field 1 of the continuation card as an identifier and hence must contain a unique entry. The continuation card contains the symbol + in column 1 followed by the same seven characters that appeared in columns 74-80 of field 10 of the card that is being continued. This allows the data to be submitted as an unsorted deck.

The small field data card should be more than adequate for the kinds of data normally associated with structural engineering problems. Since abbreviated forms of floating point numbers are allowed, up to seven significant decimal digits may be used in an eight-character field. Occasionally, however, the input is generated by another computer program or is available in a form where a wider field would be desirable. For this case, the larger field format with a 16-character data field is provided. Each logical card consists of two physical cards as indicated in the following diagram:

*See SEQGP and SEQEP for exceptions.

Large Field Bulk Data Card

1a	2	3	4	5	10a
8	16	16	16	16	8

1b	6	7	8	9	10b
8	16	16	16	16	8

The large field card is denoted by placing the symbol * after the mnemonic in field 1a and some unique character configuation in the last 7 columns of field 10a. The second physical card contains the symbol * in column 1 followed by the same seven characters that appeared after column 73 in field 10a of the first card. The second card may in turn be used to point to a large or small field continuation card, depending on whether the continuation card contains the symbol * or the symbol + in column 1. The use of multiple and large field cards are illustrated in the following examples:

Small Field Card with Small Field Continuation Card.

TYPE									QED123
+ED123									

Large Field Card

TYPE*					QED124
*ED124					

Large Field Card with Large Field Continuation Card

TYPE*					QED301
*ED301					QED302
*ED302					QED305
*ED305					

Large Field Card Followed by a Small Field Continuation Card and a Large Field Continuation Card

TYPE*									QED462
*ED462									QED421
+ED421									QED361
*ED361									QED291
*ED291									

Small Field Card with Large Field Continuation Card

TYPE									
*ED632									QED632
*ED204									QED204

In the above examples column 73 arbitrarily contains the symbol Q in all cases where field 10 is used as a pointer. However, column 73 could have been left blank or the same symbol used in column 1 of the following card could have been used (i.e., the symbols * or +).

2.4.2 Bulk Data Card Descriptions

The detailed descriptions of the bulk data cards are contained in this section in alphabetical order. For details pertaining to the use of each card and for a discussion of the cards in functional groups, the user is referred to Section 1 - Structural Modeling. Small field examples are given for each card along with a description of the contents of each field. In the Format and Example section of each card description, both a symbolic card format description and an example of an actual card are shown. Literal constants are shown in the card format section enclosed in quotes (e.g., "0"). Fields that are required to be blank are indicated in the card format section by $\boxtimes$ whenever they are followed by nonblank fields or whenever such notation will clarify the card description.

The Input File Processor will produce error messages for any cards that do not have the proper format or which contain illegal data.

Continuation cards need not be present unless they contain required data. In the case of multiple continuation cards, the intermediate cards must be present (even though fields 2-9 are blank) if one of the following cards contains data in fields 2-9. In addition, a double field format requires at least two cards (or subsequent multiples of two) so that 10 data fields are included. Thus one or more double field cards may contain no data.

Input Data Card $ Comment

Description: For user convenience in inserting commentary material into the unsorted echo of his input Bulk Data Deck. The $ card is otherwise ignored by the program. These cards will not appear in a sorted echo nor will they exist on the New Problem Tape.

Format and Example:

1	2	3	4	5	6	7	8	9	10
$	followed	by any	legitimate	characters	in card	columns	2-80		
$	THIS IS	A REMARK	(*,'$$)-+/						

Input Data Card / Delete

Description: Delete cards are used to remove cards from either the Old Problem Tape on restart or the User's Master File.

Format and Example:

1	2	3	4	5	6	7	8	9	10
/	K1	K2							
/	4								

Field	Contents
K1	Sorted sequence number of first card in sequence to be removed
K2	Sorted sequence number of last card in sequence to be removed

Remarks:
1. The delete card causes bulk data cards having sort sequence numbers K1 thru K2 to be removed from the Bulk Data Deck.
2. If K2 is blank, only card K1 is removed from the Bulk Data Deck.
3. If neither an Old Problem Tape nor a User's Master File are used in the current execution, the delete cards are ignored.

Input Data Card ADUMi   Dummy Element Attributes

Description: Defines attributes of the dummy elements ($1 \leq i \leq 9$).

Format and Example:

1	2	3	4	5	6	7	8	9	10
ADUMi	NG	NC	NP	ND					
ADUM2	8	2	1	3					

Field

NG — Number of grid points connected by DUMi dummy element (Integer > 0)

NC — Number of additional entries on CDUMi connection card (Integer $\geq$ 0)

NP — Number of additional entries on PDUMi property card (Integer $\geq$ 0)

ND — Number of displacement components at each grid point used in generation of differential stiffness matrix (Integer 3 or 6)

NASTRAN DATA DECK

Input Data Card **AEFACT** Aerodynamic Spanwise Divisions

Description: Used to specify box division points for flutter analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
AEFACT	SID	D1	D2	D3	D4	D5	D6	D7	ABC
AEFACT	97	.3	.7	1.0					
+BC	D8	D9	--etc.-						

Alternate Form:

AEFACT	SID	D1	THRU	DND	ND	DMID			
AEFACT	201	.200	THRU	.100	11	.133333			

Field	Contents
SID	Set identification number (Unique Integer > 0).
Di	Division point (Real).

Remarks:

1. These factors must be selected by a CAERØi or PAERØi data card to be used by NASTRAN.
2. Imbedded blank fields are forbidden.
3. If used to specify box division points, note that there is one more division point than the number of boxes.
4. For the alternate form, ND must be greater than 1. D_{mid} must lie between D_1 and D_{ND}, otherwise D_{mid} will be set to $(D_1 + D_{ND})/2$. Then

$$D_i = \frac{D_1(D_{ND}-D_{mid})(ND-i) + D_{ND}(D_{mid}-D_1)(i-1)}{(D_{ND}-D_{mid})(ND-i) + (D_{mid}-D_1)(i-1)} \qquad i = 1,2,\ldots,ND$$

The use of D_{mid} (middle point selection) allows unequal spacing of the points. $D_{mid} = 2D_1D_{ND}/(D_1+D_{ND})$ gives equal values to increments of the reciprocal of D_i.

Input Data Card AERØ Aerodynamic Physical Data

Description: Gives basic aerodynamic parameters.

Format and Examples:

1	2	3	4	5	6	7	8	9	10
AERØ	ACSID	VELØCITY	REFC	RHØREF	SYMXZ	SYMXY			
AERØ	3	1.3+4	100.	1.-5		1			

Field	Contents
ACSID	Aerodynamic coordinate system identification (Integer ≥ 0). See Remark 2.
VELØCITY	Velocity (Real).
REFC	Reference length (for reduced frequency) (Real).
RHØREF	Reference density (Real).
SYMXZ	Symmetry key for aero coordinate x-z plane (Integer) (+1 for sym, =0 for no sym, -1 for anti-sym).
SYMXY	Symmetry key for aero coordinate x-y plane can be used to simulate ground effects (Integer), same code as SYMXZ.

Remarks: 1. This card is required for aerodynamic response problems. Only one AERØ card is allowed.

2. The ACSID must be a rectangular coordinate system. Flow is in the positive x direction.

Input Data Card ASET Selected Coordinates

Description: Defines coordinates (degrees of freedom) that the user desires to place in the analysis set. Used to define the number of independent degrees of freedom.

Format and Example:

1	2	3	4	5	6	7	8	9	10
ASET	ID	C	ID	C	ID	C	ID	C	
ASET	16	2	23	3516			1	4	

Field	Contents
ID	Grid or scalar point identification number (Integer > 0)
C	Component number, zero or blank for scalar points, any unique combination of the digits 1-6 for grid points

Remarks:

1. Coordinates specified on ASET cards may not be specified on ØMIT, ØMIT1, ASET1, SPC or SPC1 cards nor may they appear as dependent coordinates in multipoint constraint relations (MPC) or as rigid elements (CRIGD1, CRIGD2, CRIGD3, CRIGDR) or as permanent single-point constraints on a GRID card.
2. As many as 24 coordinates may be placed in the analysis set by a single card.
3. When ASET and/or ASET1 cards are present, all degrees of freedom not otherwise constrained or referenced on a SUPØRT card, will be placed in the Ø-set.
4. ASET of ØMIT data are not recommended for use in heat transfer analysis with radiation effects.

Input Data Card ASET1 Selected Coordinates

Description: Defines coordinates (degrees of freedom) that the user desires to place in the analysis set. Used to define the number of independent degrees of freedom.

Format and Example:

1	2	3	4	5	6	7	8	9	10
ASET1	C	G	G	G	G	G	G	G	abc
ASET1	345	2	1	3	10	9	6	5	ABC

+bc	G	G	G	-etc.-					
+BC	7	8							

Alternate Form -etc.-

ASET1	C	ID1	"THRU"	ID2					
ASET1	123456	7	THRU	109					

Field	Contents
C	Component number (any unique combination of the digits 1-6 [with no imbedded blanks] when point identification numbers are grid points; must be null or zero if point identification numbers are scalar points).
G,ID1,ID2	Grid or scalar point identification numbers (Integer > 0, ID1 < ID2)

Remarks:
1. A coordinate referenced on this card may not appear as a dependent coordinate in a multipoint constraint relation (MPC card) or as a degree of freedom on a rigid element (CRIGD1, CRIGD2, CRIGD3, CRIGDR), nor may it be referenced on an SPC, SPC1, ØMIT, ØMIT1, or ASET card or on a GRID card as permanent single-point constraints.
2. When ASET and/or ASET1 cards are present, all degrees of freedom not otherwise constrained or referenced on a SUPØRT card will be placed in the Ø-set.
3. If the alternate form is used, all of the grid (or scalar) points ID1 thru ID2 are assumed.
4. ASET or ØMIT data are not recommended for use in heat transfer analysis with radiation effects.

Input Data Card AXIC Axisymmetric Problem "Flag"

Description: Defines the existence of a model containing CCØNEAX, CTRAPAX or CTRIAAX elements.

Format and Example:

1	2	3	4	5	6	7	8	9	10
AXIC	H								
AXIC	15								

Field	Contents
H	Highest harmonic defined for the problem ($0 \leq$ Integer ≤ 998)

Remarks: 1. Only one (1) AXIC card is allowed. When the AXIC card is present, most other cards are not allowed. The types which are allowed with the AXIC card are listed below.

CCØNEAX	GRAV	RLØAD1
CTRAPAX	LØAD	RLØAD2
CTRIAAX	MAT1	SECTAX
DAREA	MATT1	SPCADD
DELAY	MØMAX	SPCAX
DLØAD	MØMENT	SUPAX
DMI	MPCADD	TABDMP1
DMIG	MPCAX	TABLED1
DPHASE	NØLIN1	TABLED2
DSFACT	NØLIN2	TABLED3
EIGB	NØLIN3	TABLED4
EIGC	NØLIN4	TABLEM1
EIGP	ØMITAX	TABLEM2
EIGR	PARAM	TABLEM3
EPØINT	PCØNEAX	TABLEM4
FØRCE	PØINTAX	TEMPAX
FØRCEAX	PRESAX	TF
FREQ	PTRAPAX	TIC
FREQ1	PTRIAAX	TLØAD1
FREQ2	RFØRCE	TLØAD2
	RINGAX	TSTEP

2. For a discussion of the conical shell problem, see Section 5.9 of the Theoretical Manual.

3. For a discussion of the axisymmetric solid problem, see Section 5.11 of the Theoretical Manual.

Input Data Card AXIF Fluid Related Axisymmetric Parameters

Description: Defines basic parameters and the existence of an axisymmetric fluid analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
AXIF	CID	G	DRHØ	DB	NØSYM	F			abc
AXIF	2	32.2	0.12	2.5+5	YES				CARD-1

+bc	N1	N2	N3	N4	N5	N6	N7	N8	def
+ARD-1	1	2	3		4		7	10	

-etc.-

Alternate form of continuation card:

+bc	N1	"THRU"	Ni						def
+ARD-1	0	THRU	10						

-etc.-

Alternate form of continuation card:

+bc	N1	"THRU"	Ni	"STEP"	NS				def
+ARD-1	0	THRU	9	STEP	3				

-etc.-

Field	Contents
CID	Fluid Coordinate System identification number (Integer > 0)
G	Value of gravity for fluid elements in axial direction (Real)
DRHØ	Default mass density for fluid elements (Real > 0.0 or blank)
DB	Default bulk modulus for fluid elements (Real)
NØSYM	Request for nonsymmetric (sine) terms of series (BCD: "YES" or "NO")
F	Flag specifing harmonics (Blank - harmonic specified, or BCD - "NØNE")
Nn	Harmonic numbers for solution, an increasing sequence of integers. On the standard continuation card blanks are ignored. On the alternate form continuation cards, "THRU" implies all numbers including upper and lower integer (Blank, or integer, $0 \leq Nn < 100$, or BCD: "THRU" or "STEP")
NS	Every NSth step of the harmonic numbers specified in the "THRU" range is used for solution (Integer if field 5 is "STEP", $Ni = I \cdot NS + N1$ where I is an integer)

Remarks:
1. Only one (1) AXIF card is allowed.
2. CID must reference a cylindrical or spherical coordinate system.
3. Positive gravity (+G) implies that the direction of free fall is in the -Z direction of the Fluid Coordinate System.
4. The DRHØ value replaces blank values of RHØ on the FSLIST, BDYLIST and CFLUIDi cards.
5. The DB value replaces blank values of B on the CFLUIDi cards. If the CFLUIDi entry is blank and DB is zero or blank, the fluid is incompressible.
6. If NØSYM=YES, both sine and cosine terms are specified. If NØSYM=NØ, only cosine terms are specified.

(Continued)

AXIF (cont.)

7. If F = NØNE, no harmonics are specified, no fluid elements are necessary, and no continuation cards may be present.

Example:

1	2	3	4	5	6	7	8	9	10
AXIF	100	-386.0		0.0	NØ				+1
+1	0	THRU	50	STEP	5				+2
+2	52								+3
+3	54	THRU	57						+4
+4	61	THRU	65						+5
+5	68		71		72	75			+6
+6	81	92							END

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Input Data Card AXSLØT Axisymmetric slot analysis parameter

Description: Defines the harmonic index and the default values for acoustic analysis cards.

Format and Example:

1	2	3	4	5	6	7	8	9	10
AXSLØT	RHØD	BD	N	WD	MD				
AXSLØT	0.003	1.5+2	3	0.75	6				

Field	Contents
RHØD	Default density of fluid-mass/volume (Real $\neq$ 0.0 or blank)
BD	Default bulk modulus of fluid = (force/volume ratio change) (Real $\geq$ 0.0 or blank)
N	Harmonic index number (Integer $\geq$ 0)
WD	Default slot width (Real $\geq$ 0.0 or blank)
MD	Default number of slots (Integer $\geq$ 0 or blank)

Remarks:

1. No more than one AXSLØT card is permitted.
2. The default values are used on the GRIDS, SLBDY, CAXIFi, and CSLØTi data cards and must be nonzero as noted if these cards use the default.
3. The harmonic index number N must be entered on this card.
4. If the number of slots, M, is different in different regions or the cavity, this fact may be indicated on the CSLØTi and SLBDY cards. If the number of slots is zero, no matrices for CSLØTi elements are generated.
5. A zero entry for bulk modulus is treated as if the fluid was incompressible.

Input Data Card BARØR Simple Beam Orientation Default

Description: Defines default values for fields 3 and 6-9 of the CBAR card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
BARØR		PID			X1,GO	X2	X3	F	
BARØR		39			0.6	2.9	-5.87	1	

Field	Contents
PID	Identification number of PBAR property card (Integer > 0 or blank)
X1, X2, X3	Vector components measured in displacement coordinate system at GA to determine (with the vector from end A to end B) the orientation of the element coordinate system for the bar element (Real or blank; see below)
GO	Grid point identification number (Integer > 0; see below)
F	Flag to specify the nature of fields 6-8 as follows:

	6	7	8
F = 1	X1	X2	X3
F = 2	GO	blank	blank

Remarks:

1. The contents of fields on this card will be assumed for any CBAR card whose corresponding fields are blank.
2. Only one BARØR card may appear in the user's Bulk Data Deck.
3. For an explanation of bar element geometry, see Section 1.3.2.
4. If F=2, GO must be given even though it may be overriden on every CBAR card.

Input Data Card BDYC   Combination of Substructure Boundary Sets

Description: Defines a combination of boundary sets by basic substructure to define a set of grid points and components which may be used in a REDUCE operation.

Format and Example:

1	2	3	4	5	6	7	8	9	10
BDYC	ID	NAME1	SID1	NAME2	SID2	NAME3	SID3		ghi
BDYC	157	WINGRT	7	MIDWG	15	FUSELAGE	32		GHI
+hi		NAMEi	SIDi	etc.					jkl
+HI		PØD1	175	WINGRT	15	CABIN	16		

Field	Contents
ID	Identification number of combination boundary set (Integer > 0)
NAMEi	Name of basic substructure which contains the grid points defined by boundary set SIDi (BCD)
SIDi	Identification number of the boundary set associated with basic substructure NAMEi (Integer > 0)

Remarks:

1. Boundary sets must be selected in the Substructure Control Deck (BØUNDARY=ID) to be used by NASTRAN. Note that 'BØUNDARY' is a subcommand of the substructure REDUCE command.
2. The same substructure name may appear more than once per set.
3. The SIDi numbers need not be unique. The same number could appear for different component structures.
4. The SIDi numbers reference the set ID's of BDYS and BDYS1 cards.
5. The ID number must be unique with respect to all other BDYC data cards.
6. After two or more basic substructures are combined, the connected degrees of freedom are actually the same and may be referenced with any one of the substructure names. Redundant specification is allowed.

Input Data Card BDYLIST Fluid Boundary List

Description: Defines the boundary between a fluid and a structure.

Format and Example:

1	2	3	4	5	6	7	8	9	10
BDYLIST	RHØ	IDF1	IDF2	IDF3	IDF4	IDF5	IDF6	IDF7	abc
BDYLIST	.037	432	325	416	203	256	175	153	345A
+bc	IDF8	etc.							def
+45A	101	105	AXIS						

-etc.-

Field	Contents
RHØ	Fluid mass density at boundary (Real ≥ 0.0 or blank. Default on AXIF card is used if blank)
IDFi	Identification number of a RINGFL point (Integer > 0 or BCD. "AXIS" may be first and/or last entry on the logical card)

Remarks:

1. This card is allowed only if an AXIF card is also present.
2. Each logical card defines a boundary if RHØ ≠ 0.0. The order of the points must be sequential with the fluid on the right with respect to the direction of travel.
3. The BCD word, AXIS, defines an intersection with the polar axis of the fluid coordinate system.
4. There may be as many BDYLIST cards as the user requires. If the fluid density varies along the boundary there must be one BDYLIST card for each interval between fluid points.
5. The BDYLIST card is not required and should not be used to specify a rigid boundary where structural points are not defined. Such a boundary is automatically implied by the omission of a BDYLIST.
6. If RHØ is 0.0, no boundary matrix terms will be generated to connect the GRIDB points to the fluid. This option is a convenience for structural plotting purposes. GRIDB points may be located on a fluid ring (RINGFL) only if the rings are included in a BDYLIST.

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Input Data Card BDYS Boundary Set Definition

Description: This card is used to define a boundary set of grid points and degrees of freedom for a basic substructure. The boundary set is used in the substructure REDUCE, CREDUCE and MREDUCE operations.

Format and Example:

1	2	3	4	5	6	7	8	9	10
BDYS	SID	G1	C1	G2	C2	G3	C3		
BDYS	7	13	123456	15	123	17	123456		

Field	Contents
SID	Identification number of BDYS set (Integer > 0)
Gi	Grid or scalar point identification number of a basic substructure (Integer > 0)
Ci	Component number - Any unique combination of the digits 1 - 6 (with no imbedded blanks) when the Gi are grid points, or null if they are scalar points.

Remarks:

1. The set of boundary points defines the degrees of freedom which are to be retained in the matrices after the substructure REDUCE, CREDUCE or MREDUCE operation has been performed. An alternate input format is provided by the BDYS1 card.

2. The SID need not be unique.

3. The BDYS card must be referenced by the BDYC card in order to attach the basic substructure name to the boundary set specified on the BDYS card. Note that the same BDYS boundary set may be attached to more than one basic substructure name.

Input Data Card BDYS1 Boundary Set Definition

Description: This card is used to define a boundary set of grid points and degrees of freedom for a basic substructure. The boundary set is used in the substructure REDUCE, CREDUCE and MREDUCE operations.

Format and Examples:

1	2	3	4	5	6	7	8	9	10
BDYS1	SID	C	G1	G2	G3	G4	G5	G6	abc
BDYS1	15	123456	275	276	THRU	457	589	102	ABC
+bc	G7	G8	etc.		GN				
+BC	103	105			1275				

Field	Contents
SID	Identification number of BDYS1 set (Integer > 0)
Ci	Component number - Any unique combination of the digits 1 - 6 (with no imbedded blanks) when the Gi are grid points, or null if they are scalar points.
Gi	Grid or scalar point identification number of a basic substructure (Integer > 0)

Remarks:

1. The set of boundary points defines the degrees of freedom which are to be retained in the matrices after the substructure REDUCE, CREDUCE or MREDUCE operation has been performed. An alternate format is provided by the BDYS card.

2. The "THRU" may appear in any field other than 2 and 9.

3. The SID need not be unique.

4. The BDYS1 card must be referenced by the BDYC card in order to attach the basic substructure name to the boundary set specified on the BDYS card. Note that the same BDYS boundary set may be attached to more than one basic substructure name.

Input Data Card BFIELD - Magnetic Induction Output

Description: Specifies coordinate system for magnetic induction output.

Format and Example:

1	2	3	4	5	6	7	8	9	10
BFIELD	CID	EID1	EID2	EID3	EID4	EID5	EID6	EID7	
BFIELD	3	12	5	6					

First Alternate Form:

BFIELD	CID	EID1	"THRU"	EID2					
BFIELD	5	8	THRU	27					

Second Alternate Form:

BFIELD	CID	-1							
BFIELD	7	-1							

Field	Contents
CID	Coordinate system identification number (Integer > 0 or blank)
EIDi	Element identification numbers of those elements whose magnetic induction are to be output in coordinate system CID (Integer > 0)

Remarks:

1. The magnetic induction of any element not specified on a BFIELD card will be computed in the basic coordinate system. Therefore, no BFIELD cards are necessary if CID = 0 for all elements.

2. If the first alternate form of the card is used, all element identification numbers between EID1 and EID2 need not exist, but sufficient core must be available for 2(EID2 - EID1 + 1) words.

3. The second alternate form of the card implies that the magnetic induction values of all elements in the problem will be computed in coordinate system CID.

Input Data Card CAERØ1 Aerodynamic Panel Element Connection

Description: Defines an aerodynamic macro element (panel) in terms of two leading edge locations and side chords for Doublet-Latice Theory.

Format and Example:

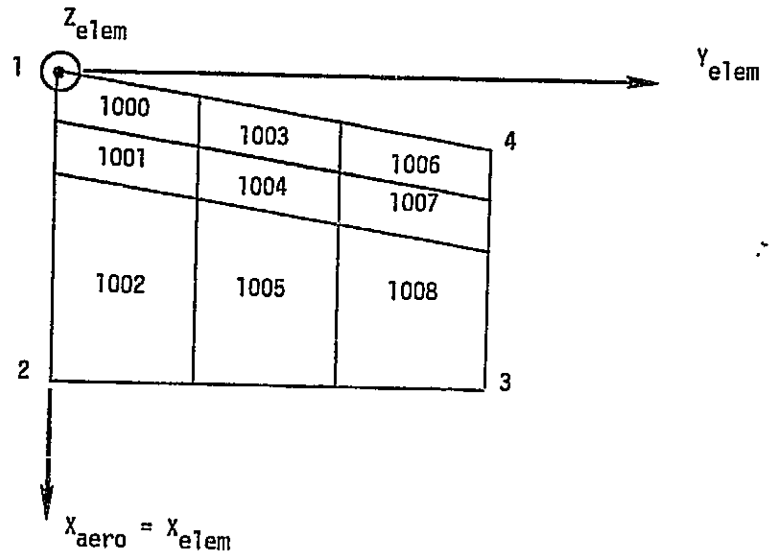
1	2	3	4	5	6	7	8	9	10
CAERØ1	EID	PID	CP	NSPAN	NCHØRD	LSPAN	LCHØRD	IGID	ABC
CAERØ1	1000	1		3			2	1	ABC
+BC	X1	Y1	Z1	X12	X4	Y4	Z4	X43	
+BC	0.0	0.0	0.0	1.0	0.2	1.0	0.0	0.8	

Field	Contents
EID	Element identification number (unique Integer > 0).
PID	Identification number of property card (Integer > 0) to specify associated bodies.
CP	Coordinate system for locating points 1 and 4 (Integer ≥ 0).
NSPAN	Number of spanwise boxes; if a positive value is given, equal divisions are assumed; if zero or blank, a list of division points follows (Integer ≥ 0).
NCHØRD	Number of chordwise boxes (same rule as for NSPAN).
LSPAN	ID of an AEFACT data card containing a list of division points for spanwise boxes. Used only if field 5 is zero or blank (Integer > 0 if NSPAN is zero or blank).
LCHØRD	ID of an AEFACT data card containing a list of division points for chordwise boxes. Used only if field 6 is zero or blank (Integer > 0 if NCHØRD is zero or blank).
IGID	Interference group identification (aerodynamic elements with different IGID's are uncoupled) (Integer > 0).
X1,Y1,Z1;X4,Y4,Z4	Location of points 1 and 4, in coordinate system CP (Real).
X12; X43	Edge chord length (in aerodynamic coordinate system) (Real ≥ 0, and not both zero).

(Continued)

CAERØ1 (Cont.)

Remarks:



1. The boxes are numbered sequentially, beginning with EID. The user should be careful to ensure that all box numbers are unique, and different from structural grid ID's.
2. The number of division points is one greater than the number of boxes. Thus, if NSPAN = 3, the division points are 0.0, 0.333, 0.667, 1.000. If the user supplies division points, the first and last points need not be 0. and 1. (in which the corners of the panel would not be at the reference points).
3. A triangular element is formed if X12 or X43 = 0.
4. The element coordinate system (right-handed) is shown in the sketch.
5. The continuation card is required.

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Input Data Card CAERØ2 Aerodynamic Body Connection

Description: Defines an aerodynamic body for Doublet-Lattice aerodynamics.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CAERØ2	EID	PID	CP	NSB	NINT	LSB	LINT	IGID	ABC
CAERØ2	1500	2	100		4	99		1	abc
+BC	X1	Y1	Z1	X12					
+bc	-1.0	100.	-30.	175.					

Field	Contents
EID	Element identification number (Integer > 0).
PID	Property identification number (Integer > 0).
CP	Coordinate system for locating point 1 (Integer ≥ 0).
NSB	Number of slender body elements; if a positive number is given, NSB equal divisions are assumed; if zero or blank, see field 7 for a list of divisions (Integer ≥ 0).
NINT	Number of interference elements; if a positive number is given, NINT equal divisions are assumed; if zero or blank, see field 8 for a list of divisions (Integer ≥ 0).
LSB	ID of an AEFACT data card for slender body division points; used only if field 5 is zero or blank (Integer ≥ 0).
LINT	ID of an AEFACT data card containing a list of division points for interference elements used only if field 6 is zero or blank (Integer ≥ 0).
IGID	Interference group identification (aerodynamic elements with different IGID's are uncoupled) (Integer > 0).
X1,Y1,Z1	Location of point 1 in coordinate system CP (Real).
X12	Length of body in the x-direction of the aerodynamic coordinate system (Real > 0).

Remarks:

1 Point 1 is the leading point of the body.

2. All CAERØ1 (panels) and CAERØ2 (bodies) in the same group (IGID) will have aerodynamic interaction.

3. Interference elements are optional, but if used at least one element is required for each aerodynamic body specified by this card.

4. Element identification numbers on the aerodynamic bodies must have the following sequence:

   (a) CAERØ1 Panels first (lowest number)

   (b) Z-bodies (see PAERØ2 ØRIENTation flag)

   (c) ZY-bodies

   (d) Y-bodies (highest number)

(Continued)

and they must be unique with respect to all structural grid ID's.

5. The total number of interference bodies associated with a panel is limited to six.

6. At least two slender body elements are required for every aerodynamic body specified by this card.

Input Data Card CAERØ3 Aerodynamic Mach Box Surface Connection

Description: Defines the aerodynamic edges of a Mach Box lifting surface. If no cranks are present, this card defines the aerodynamic Mach Box lifting surface.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CAERØ3	EID	PID	CP	LISTW	LISTC1	LISTC2			ABC
CAERØ3	2000	2001	0	22	33				abc
+BC	X1	Y1	Z1	X12	X4	Y4	Z4	X43	
+bc	1.0	0.0	0.0	100.	17.	130.	0.	100.	

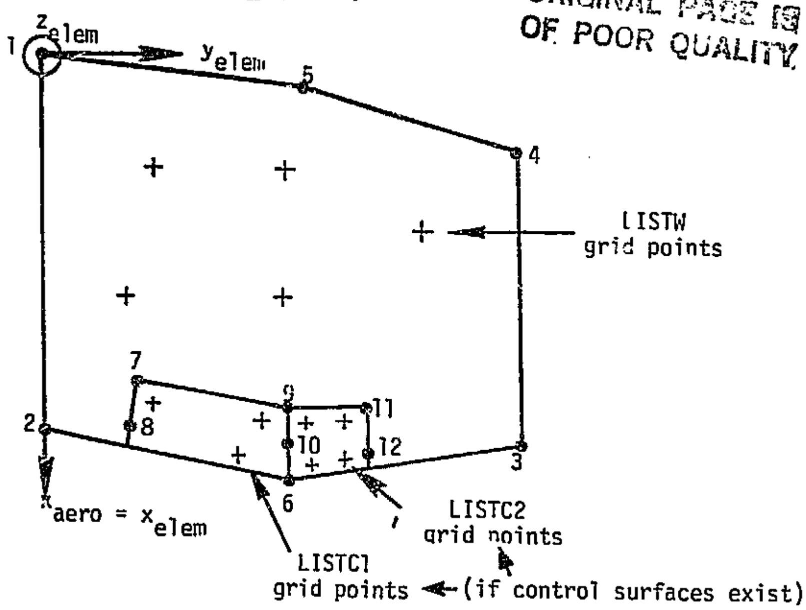
Field	Contents
EID	Element identification number (Integer > 0).
PID	Property identification number (Integer > 0).
CP	Coordinate system for locating points 1 and 4 (Integer ≥ 0).
LISTW	The ID of an AEFACT data card which lists (x,y) pairs of structural interpolation grid points of the wing (Integer > 0).
LISTC1 LISTC2	The ID of AEFACT data cards which list (x,y) pairs for controls (if they exist) (Integers ≥ 0).
X1,Y1,Z1 X4,Y4,Z4	Location of points 1 and 4 in coordinate system CP (Real).
X12,X43	Edge chord lengths (in aerodynamic coordinate system) Real ≥ 0, X12 ≠ 0.).

Remarks:

1. The x,y pairs of LISTW, LISTC1, and LISTC2 (AEFACT) data cards are in the aero element coordinate system.
2. If cranks and/or control surfaces exist, their locations are given on the PAERØ3 data card.
3. The numbering system and coordinate system are shown on the next page.

(Continued)

CAERØ3 (Cont.)



The following twelve points are defined for each Mach Box lifting surface.

Planform Corners

1. Leading edge, inboard
2. Trailing edge, inboard
3. Trailing edge, outboard
4. Leading edge, outboard

Cranks

5. Leading edge
6. Trailing edge

Control

7. Hinge line, inboard
8. On inboard edge (usually at trailing edge)
9. Hinge line, outboard
10. On outboard edge

Control (if two)

9. Hinge line, inboard
10. On inboard edge (usually at trailing edge)
11. Hinge line, outboard
12. On outboard edge (usually at trailing edge)

NASTRAN DATA DECK

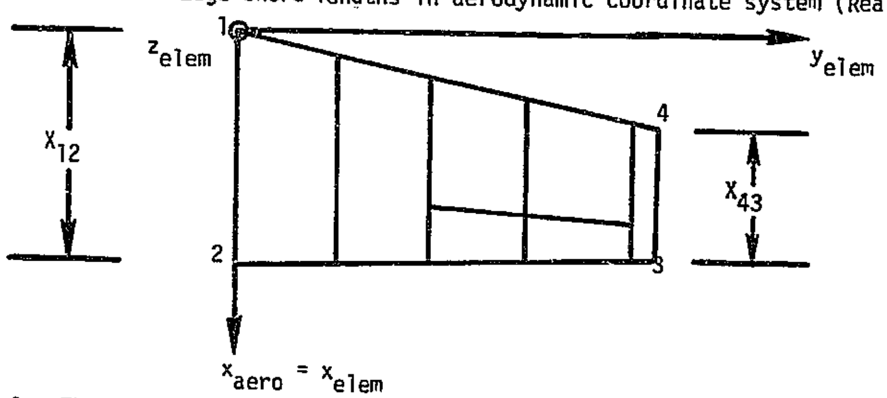
Input Data Card CAERØ4 Aerodynamic Macro-Strip Element Connection

Description: Defines an aerodynamic macro element for strip theory.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CAERØ4	EID	PID	CP	NSPAN	LSPAN				ABC
CAERØ4	6000	6001	100		315				abc
+BC	X1	Y1	Z1	X12	X4	Y4	Z4	X43	
+bc	0.0	0.0	0.0	1.0	0.2	1.0	0.0	0.8	

Field	Contents
EID	Element identification number (Integer > 0)
PID	Property identification number (Integer > 0)
CP	Coordinate system for locating points 1 and 4 (Integer ≥ 0)
NSPAN	Number of strips; if a positive value is given, NSPAN equal strips are assumed. If zero or blank, use LSPAN field (Integer ≥ 0).
LSPAN	ID of an AEFACT data card containing a list of division points for strips. Used only if field 5 is zero or blank (Integer > 0 if NSPAN is zero or blank).
X1,Y1,Z1 X4,Y4,Z4	Location of points 1 and 4 in coordinate system CP (Real)
X12,X43	Edge chord lengths in aerodynamic coordinate system (Real ≥ 0, and not both zero).



Remarks:

1. The strips are numbered sequentially, beginning with EID. The user must ensure that all strip numbers are unique and different from structural grid ID's.

2. The number of division points is one greater than the number of boxes. Thus, if NSPAN = 3, the division points are 0.0, 0.333, 0.667, 1.000. If the user supplies division points, the first and last points need not be 0. and 1. (in which case the corners of the panel would not be at the reference points).

3. A triangular element is formed if X12 <u>or</u> X43 = 0.

Input Data Card CAERØ5 Aerodynamic Macro-Piston Theory Element Connection

Description: Defines an aerodynamic macro-element for Piston Theory.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CAERØ5	EID	PID	CP	NSPAN	LSPAN	NTHRY	NTHICK		ABC
CAERØ5	6000	6001	100		315	0	0		abc
+BC	X1	Y1	Z1	X12	X4	Y4	Z4	X43	
+bc	0.0	0.0	0.0	1.0	0.2	1.0	0.0	0.8	

Field | Contents

EID Element identification number (Integer > 0).

PID Property identification number (Integer > 0).

CP Coordinate system for locating points 1 and 4 (Integer ≥ 0).

NSPAN Number of strips; if a positive value is given, NSPAN equal strips are assumed. If zero or blank, use LSPAN field.

LSPAN ID of an AEFACT data card containing a list of division points for strips. Used only if field 5 is zero or blank (Integer > 0 if NSPAN is zero or blank).

NTHRY Parameter to select the theory (Integer 0, blank, 1, or 2). See Remark 4.

0 - Use Piston Theory.

1 - Use Van Dyke Theory (no sweep correction, $\sec\Lambda = 1.$).

2 - Use Van Dyke theory with sweep correction.

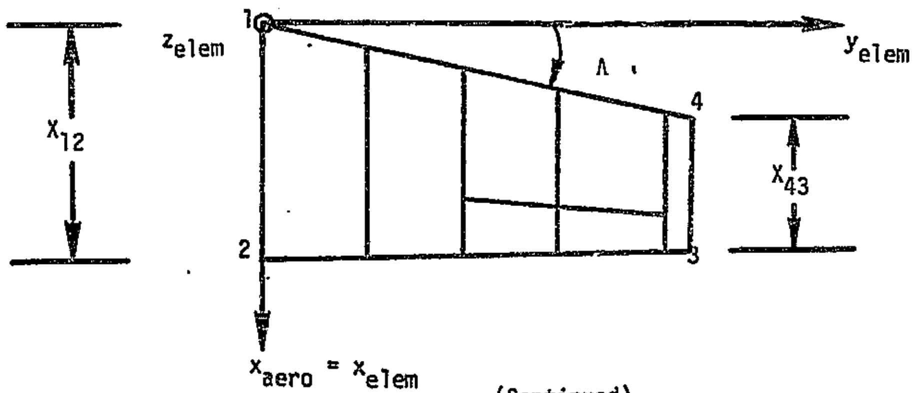
NTHICK Parameter to select thickness integrals input (Integer ≥ 0 or blank).

0 - Thickness integrals are computed internally.

>0 - Thickness integrals are input directly and is the ID number of AEFACT data card which lists the I and/or J integrals.

X1,Y1,Z1
X4,Y4,Z4 Location of points 1 and 4 in coordinate system CP (Real).

X12,X43 Edge chord lengths in aerodynamic coordinate system (Real ≥ 0, and not both zero).

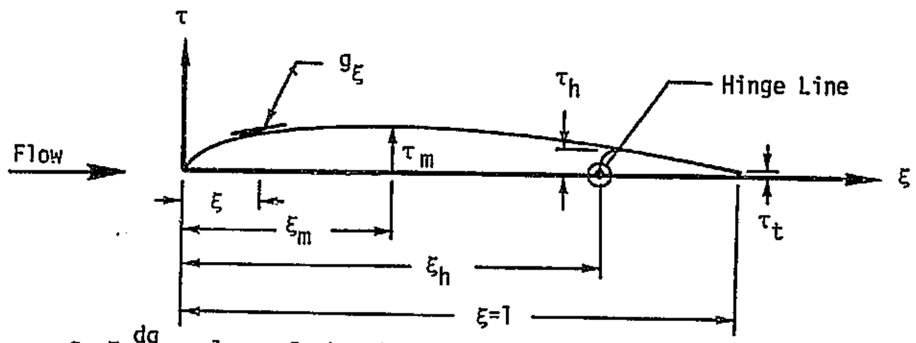


(Continued)

CAERØ5 (Cont.)

Remarks:

1. The strips are numbered sequentially, beginning with EID. The user must ensure that all strip numbers are unique and different from structural grid ID's.
2. The number of division points is one greater than the number of boxes. Thus, if NSPAN = 3, the division points are 0.0, 0.333, 0.667, 1.000. If the user supplies division points, the first and last points need not be 0. and 1. (in which the corners of the panel would not be at the reference points).
3. A triangular element is formed if X12 or X43 = 0.
4. Three separate "piston theory" formulations are available (see Section 1.11.2.5).
5. I and J thickness integral definitions:



$g_\xi \equiv \frac{dg}{d\xi}$ = slope of airfoil semithickness

$$I_1 = \int_0^1 g_\xi d\xi \qquad J_1 = \int_{\xi_h}^1 g_\xi d\xi$$

$$I_2 = \int_0^1 \xi g_\xi d\xi \qquad J_2 = \int_{\xi_h}^1 \xi g_\xi d\xi$$

$$I_3 = \int_0^1 \xi^2 g_\xi d\xi \qquad J_3 = \int_{\xi_h}^1 \xi^2 g_\xi d\xi$$

$$I_4 = \int_0^1 g_\xi^2 d\xi \qquad J_4 = \int_{\xi_h}^1 g_\xi^2 d\xi$$

$$I_5 = \int_0^1 \xi g_\xi^2 d\xi \qquad J_5 = \int_{\xi_h}^1 \xi g_\xi^2 d\xi$$

$$I_6 = \int_0^1 \xi^2 g_\xi^2 d\xi \qquad J_6 = \int_{\xi_h}^1 \xi^2 g_\xi^2 d\xi$$

See PAERØ5 for a method to have these integrals computed internally.

Input Data Card CAXIFi Fluid Element Connections

Description: Defines an axisymmetric fluid element which connects i = 2, i = 3, or i = 4 fluid points.

Formats and Examples:

1	2	3	4	5	6	7	8	9	10
CAXIF2	EID	IDF1	IDF2			RHØ	B		
CAXIF2	11	23	25			.25E-03			
CAXIF3	EID	IDF1	IDF2	IDF3		RHØ	B		
CAXIF3	105	31	32	33			6.7E4		
CAXIF4	EID	IDF1	IDF2	IDF3	IDF4	RHØ	B		
CAXIF4	524	421	425	424	422	.5-3	2.5+3		

Field	Contents
EID	Element identification number (Integer > 0)
IDFj	Identification numbers of connected GRIDF points, j = 1,2,...i (Integer > 0)
RHØ	Fluid density in mass units (Real > 0.0 or blank)
B	Fluid bulk modulus (Real ≥ 0.0 or blank)

Remarks:

1. This card is allowed only if an AXSLØT card is also present.

2. The element identification number (EID) must be unique with respect to all other fluid or structural elements.

3. If RHØ, or B are "blank" the corresponding values on the AXSLØT data card are used, in which case the default must not be blank (undefined).

4. Plot elements are generated for these elements. Because each plot element connects two points, one is generated for the CAXIF2 element, three are generated for the CAXIF3 element, and four plot elements are generated for the CAXIF4 element. In the last case the elements connect the pairs of points (1-2), (2-3), (3-4) and (4-1).

5. If B = 0.0, the fluid is considered to be incompressible.

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Input Data Card CBAR Simple Beam Element Connection

Description: Defines a simple beam element (BAR) of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CBAR	EID	PID	GA	GB	X1,GO	X2	X3	F	abc
CBAR	2	39	7	3	13			2	123
+bc	PA	PB	Z1A	Z2A	Z3A	Z1B	Z2B	Z3B	
+23		513							

Field	Contents
EID	Unique element identification number (Integer > 0)
PID	Identification number of a PBAR property card (Default is EID unless BARØR card has nonzero entry in field 3) (Integer > 0 or blank*)
GA,GB	Grid point identification numbers of connection points (Integer > 0; GA ≠ GB)
X1,X2,X3	Components of vector $\vec{v}$, at end a, (figure 1(a) on page 1.3-15) measured at end a, parallel to the components of the displacement coordinate system for GA, to determine (with the vector from end a to end b) the orientation of the element coordinate system for the bar element (Real, $X1^2 + X2^2 + X3^2 > 0$ or blank*, see below).
GO	Grid point identification number to optionally supply X1, X2, X3 (integer > 0 or blank*) (see below)
F	Flag to specify the nature of fields 6-8 as follows:

	6	7	8
F = blank*			
F = 1	X1	X2	X3
F = 2	GO	blank/0	blank/0

Field	Contents
PA,PB	Pin flags for bar ends a and b, respectively, that are used to insure that the bar cannot resist a force or moment corresponding to the pin flag at that respective end of the bar. (Up to 5 of the unique digits 1-6 anywhere in the field with no imbedded blanks; integer > 0) (These degree of freedom codes refer to the element forces and not global forces. The bar must have stiffness associated with the pin flag. For example, if pin flag 4 is specified, the bar must have a value for J, the torsional constant.)
Z1A,Z2A,Z3A Z1B,Z2B,Z3B	Components of offset vectors $\vec{w}_a$ and $\vec{w}_b$, respectively, (see figure 1(a), page 1.3-15) in displacement coordinate systems at points GA and GB, respectively. (Real or blank)

(Continued)

*See the BARØR card for default options for fields 3, 6, 7, 8 and 9.

CBAR (Cont.)

Remarks: 1. Element identification numbers must be unique with respect to all other element identification numbers.

2. For an explanation of bar element geometry, see Section 1.3.2.

3. Zero (0) must be used in fields 7 and 8 in order to override entries in these fields associated with F = 1 in field 9 on a BARØR card.

4. If there are no pin flags or offsets, the continuation card may be omitted.

Input Data Card CCØNEAX Axisymmetric Shell Element Connection

Description: Defines the connection of a conical shell element.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CCØNEAX	ID	PID	RA	RB					
CCØNEAX	1	2	3	4					

Field	Contents
EID	Unique element identification number (1 ≤ Integer ≤ 9999)
PID	Identification number of a PCØNEAX card (Default is EID) (Integer > 0)
RA	Identification number of a RINGAX card (Integer > 0; RA ≠ RB)
RB	Identification number of a RINGAX card (Integer > 0; RA ≠ RB)

Remarks: 1. This card is allowed if and only if an AXIC card is also present.

2. For a discussion of the conical shell problem, see Section 5.9 of the Theoretical Manual.

Input Data Card CDAMP1 Scalar Damper Connection

Description: Defines a scalar damper element of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CDAMP1	EID	PID	G1	C1	G2	C2			
CDAMP1	19	6	0		23	2			

Field	Contents
EID	Unique element identification number (Integer > 0)
PID	Identification number of a PDAMP property card (Default is EID) (Integer > 0)
G1, G2	Geometric grid point identification number (Integer $\geq$ 0)
C1, C2	Component number (6 $\geq$ Integer $\geq$ 0)

Remarks:
1. Scalar points may be used for G1 and/or G2 in which case the corresponding C1 and/or C2 must be zero or blank. Zero or blank may be used to indicate a grounded* terminal G1 or G2 with a corresponding blank or zero C1 or C2. If only scalar points and/or ground are involved, it is more efficient to use the CDAMP3 card.
2. Element identification numbers must be unique with respect to all other element identification numbers.
3. The two connection points, (G1, C1) and (G2, C2), must be distinct.
4. For a discussion of the scalar elements, see Section 5.6 of the Theoretical Manual.
5. In heat transfer analysis, the CDAMP1 card may be used to define a lumped thermal capacitance ($Q=B\dot{T}$) if connected to grid point S1.

*A grounded terminal is a scalar point or coordinate of a geometric grid point whose displacement is constrained to zero.

Input Data Card CDAMP2 Scalar Damper Property and Connection

Description: Defines a scalar damper element of the structural model without reference to a property value.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CDAMP2	EID	B	G1	C1	G2	C2			
CDAMP2	16	-2.98	32	1					

Field	Contents
EID	Unique element identification number (Integer > 0)
B	The value of the scalar damper (Real)
G1, G2	Geometric grid point identification number (Integer $\geq$ 0)
C1, C2	Component number (6 $\geq$ Integer $\geq$ 0)

Remarks: 1. Scalar points may be used for G1 and/or G2 in which case the corresponding C1 and/or C2 must be zero or blank. Zero or blank may be used to indicate a grounded* terminal G1 or G2 with a corresponding blank or zero C1 or C2. If only scalar points and/or ground are involved, it is more efficient to use the CDAMP4 card.

2. Element identification numbers must be unique with respect to all other element identification numbers.

3. This single card completely defines the element since no material or geometric properties are required.

4. The two connection points, (G1, C1) and (G2, C2), must be distinct.

5. For a discussion of the scalar elements, see Section 5.6 of the Theoretical Manual.

6. In heat transfer analysis the CDAMP2 card may be used to define a lumped thermal capacitance ($Q=B\dot{T}$) if connected to grid point S1.

*A grounded terminal is a scalar point or coordinate of a geometric grid point whose displacement is constrained to zero.

Input Data Card CDAMP3 Scalar Damper Connection

Description: Defines a scalar damper element of the structural model which is connected only to scalar points.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CDAMP3	EID	PID	S1	S2	EID	PID	S1	S2	
CDAMP3	16	978	24	36	17	978	24	37	

Field	Contents
EID	Unique element identification number (Integer > 0)
PID	Identification number of a PDAMP property card (Default is EID) (Integer > 0)
S1, S2	Scalar point identification numbers (Integer $\geq$ 0; S1 $\neq$ S2)

Remarks:

1. S1 or S2 may be blank or zero indicating a constrained coordinate.
2. Element identification numbers must be unique with respect to all other element identification numbers.
3. One or two scalar damper elements may be defined on a single card.
4. For a discussion of the scalar elements, see Section 5.6 of the Theoretical Manual.
5. In heat transfer analysis the CDAMP3 card may be used to define a lumped thermal capacitance ($Q=B\dot{T}$) if connected to grid point S1.

Input Data Card CDAMP4 Scalar Damper Property and Connection

Description: Defines a scalar damper element of the structural model which is connected only to scalar points.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CDAMP4	EID	B	S1	S2	EID	B	S1	S2	
CDAMP4	16	-2.6	4	9	17	+8.6	3	7	

Field	Contents
EID	Unique element identification number (Integer > 0)
B	The scalar damper value (Real)
S1, S2	Scalar point identification numbers (Integer $\geq$ 0; S1 $\neq$ S2)

Remarks:

1. S1 or S2 may be blank or zero indicating a constrained coordinate.
2. Element identification numbers must be unique with respect to all other element identification numbers.
3. This card completely defines the element since no material or geometric properties are required.
4. One or two scalar damper elements may be defined on a single card.
5. For a discussion of the scalar elements, see Section 5.6 of the Theoretical Manual.
6. In heat transfer analysis the CDAMP4 card may be used to define a lumped thermal capacitance ($Q=B\dot{T}$) if connected to grid point S1.

Input Data Card CDUMi Dummy Element Connection

Description: Defines a dummy element ($1 \leq i \leq 9$).

Format and Example:

1	2	3	4	5	6	7	8	9	10
CDUMi	EID	PID	G1	G2	G3	G4	-etc.-	GN	abc
CDUM2	114	108	2	5	6	8		11	ABC
+bc	A1	A2	-etc.-			AN			
+BC	2.4		3.E4	2		50			

Field	Contents
EID	Element identification number (Integer > 0)
PID	Identification number of a PDUMi property card (Integer > 0)
G1...GN	Grid point identification numbers of connection points (Integer > 0, G1 ≠ G2 ... ≠ GN)
A1...AN	Additional entries (Real or Integer)

Remarks:

1. The user must code the associated element routines for matrix generation, stress recovery, etc., and perform a link edit to replace the dummy routines.
2. If no property card is required, field 3 may contain the material identification number.
3. Additional entries are defined in the user written element routines.

NASTRAN DATA DECK

Input Data Card CELAS1 Scalar Spring Connection

Description: Defines a scalar spring element of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CELAS1	EID	PID	G1	C1	G2	C2			
CELAS1	2	6			8	1			

Field	Contents
EID	Unique element identification number (Integer > 0)
PID	Identification number of a PELAS property card (Default is EID) (Integer > 0)
G1, G2	Geometric grid point identification number (Integer > 0)
C1, C2	Component number ($6 \geq$ Integer ≥ 0)

Remarks:

1. Scalar points may be used for G1 and/or G2 in which case the corresponding C1 and/or C2 must be zero or blank. Zero or blank may be used to indicate a grounded* terminal G1 or G2 with a corresponding blank or zero C1 or C2. If only scalar points and/or ground are involved, it is more efficient to use the CELAS3 card.

2. Element identification numbers must be unique with respect to all other element identification numbers.

3. The two connection points, (G1, C1) and (G2, C2), must be distinct.

4. For a discussion of the scalar elements, see Section 5.6 of the Theoretical Manual.

5. In heat transfer analysis the CELAS1 card may be used to define a conduction or convection between two points or to ground ($Q = K\Delta T$).

*A grounded terminal is a scalar point or coordinate of a geometric grid point whose displacement is constrained to zero.

Input Data Card CELAS2 Scalar Spring Property and Connection

Description: Defines a scalar spring element of the structural model without reference to a property value.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CELAS2	EID	K	G1	C1	G2	C2	GE	S	
CELAS2	28	6.2+3	32		19	4			

Field	Contents
EID	Unique element identification number ($0 <$ Integer $\leq 10^7$ if acoustic)
K	The value of the scalar spring (Real)
G1, G2	Geometric grid point identification number (Integer ≥ 0)
C1, C2	Components number ($6 \geq$ Integer ≥ 0)
GE	Damping coefficient (Real)
S	Stress coefficient (Real)

Remarks:

1. Scalar points may be used for G1 and/or G2 in which case the corresponding C1 and/or C2 must be zero or blank. Zero or blank may be used to indicate a grounded* terminal G1 or G2 with a corresponding blank of zero C1 or C2. If only scalar points and/or ground are involved, it is more efficient to use the CELAS4 card.
2. Element identification numbers must be unique with respect to all other element identification numbers.
3. This single card completely defines the element since no material or geometric properties are required.
4. The two connection points, (G1, C1) and (G2, C2), must be distinct.
5. For a discussion of the scalar elements, see Section 5.6 of the Theoretical Manual.
6. In heat transfer analysis the CELAS2 card may be used to define a conduction or convection between two points or to ground ($Q=K\Delta T$).

*A grounded terminal is a scalar point or coordinate of a geometric grid point whose displacement is constrained to zero.

Input Data Card CELAS3 Scalar Spring Connection

Description: Defines a scalar spring element of the structural model which is connected only to scalar points.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CELAS3	EID	PID	S1	S2	EID	PID	S1	S2	
CELAS3	19	2	14	15	2	3	0	28	

Field	Contents
EID	Unique element identification number (Integer > 0)
PID	Identification number of a PELAS property card (Default is EID) (Integer > 0)
S1, S2	Scalar point identification numbers (Integer $\geq$ 0; S1 $\neq$ S2)

Remarks:
1. S1 or S2 may be blank or zero indicating a constrained coordinate.
2. Element identification numbers must be unique with respect to all other element identification numbers.
3. One or two scalar springs may be defined on a single card.
4. For a discussion of the scalar elements, see Section 5.6 of the Theoretical Manual.
5. In heat transfer analysis the CELAS3 card may be used to define a conduction or convection between two points or to ground ($Q=K\Delta T$).

Input Data Card CELAS4 Scalar Spring Property and Connection

Description: Defines a scalar element of the structural model which is connected only to scalar points without reference to a property value.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CELAS4	EID	K	S1	S2	EID	K	S1	S2	
CELAS4	42	6.2-3	2		13	6.2-3	0	2	

Field	Contents
EID	Unique element identification number (Integer > 0)
K	The scalar spring value (Real)
S1, S2	Scalar point identification numbers (Integer $\geq$ 0; S1 $\neq$ S2)

Remarks:
1. S1 or S2 but not both may be blank or zero indicating a constrained coordinate.
2. Element identification numbers must be unique with respect to all other element identification numbers.
3. This card completely defines the element since no material or geometric properties are required.
4. No damping coefficient is available with this form. (Assumed to be 0.0)
5. No stress coefficient is available with this form.
6. One or two scalar springs may be defined on a single card.
7. For a discussion of the scalar elements, see Section 5.6 of the Theoretical Manual.
8. In heat transfer analysis the CELAS4 card may be used to define a conduction or convection between two points or to ground ($Q=K\Delta T$).

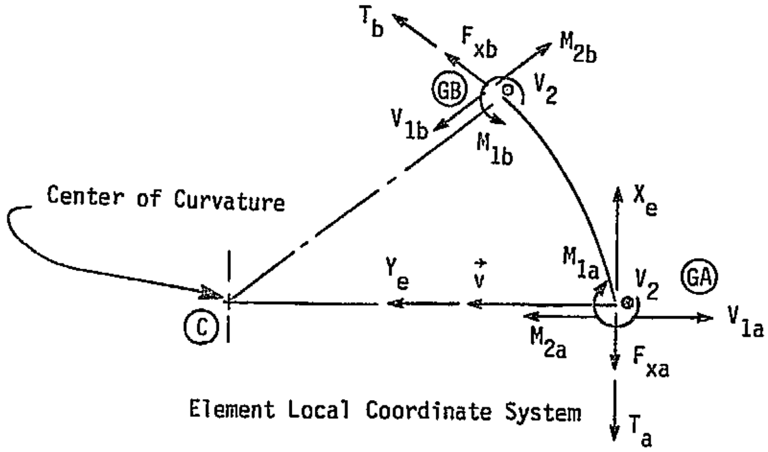
Input Data Card CELBØW - Curved Beam or Elbow Element

Description: Defines a curved beam or elbow element of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CELBØW	EID	PID	GA	GB	X1	X2	X3	1	
CELBØW	29	2	3	45	-1.0	0.0	0.0	1	

Field	Contents
EID	Element identification number (Integer > 0)
PID	Identification number of a PELBØW property card (Integer > 0)
GA,GB	Grid point identification numbers of connection points (Integer > 0; GA ≠ GB)
X1,X2,X3	Components of vector $\vec{v}$ at end A (see figure below), measured at end A, parallel to the components of the displacement coordinates for GA. Vector points the direction from GA to C (center of curvature), and is used to orient the element coordinate system for the ELBØW (real, $X1^2 + X2^2 + X3^2 > 0$).



Element Local Coordinate System

Remarks:

1. The product moment of inertia is neglected (I12 = 0). This assumes that at least one axis of symmetry of the element cross section exists, e.g., tube, I-beam, channel, tee, etc.

2. Element identification numbers must be unique with respect to all other element identification numbers.

3. There are no pin flags or offsets permitted with the ELBØW element.

4. The local element coordinate system is shown in the figure above. Plane 1 contains the points GA and GB and the vector $\vec{v}$. Plane 2 is normal to Plane 1 and contains the vector $\vec{v}$.

(Continued)

CELBØW (Cont.)

5. Element forces and stresses are oriented in the element coordinate system at the A-end, and in a rotated coordinate system at the B-end which is tangent to the curved beam at the B-end.

6. Field 9 must always have an integer value of 1.

Input Data Card CEMLØØP - Circular Current Loop

Description: Defines a circular current loop in magnetic field problems.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CEMLØØP	SID	I	AXI	X1	Y1	Z1	X2	Y2	+a
CEMLØØP	3	2.5	1	5.2	0.0	2.25			

+a	Z2	XC	YC	ZC	CID				

Field	Contents
SID	Load set identification number (Integer > 0)
I	Current through loop (units of positive charge/sec) (Real > 0.0)
AXI	= 0, nonaxisymmetric problem = 1, axisymmetric problem; TRAPRG and TRIARG elements are implied (Integer)
X1,Y1,Z1 X2,Y2,Z2	Coordinates of two points through which the loop passes (given in coordinate system CID) (Real)
XC,YC,ZC	Coordinates of center of loop (given in coordinate system CID) (Real)
CID	Coordinate system identification number (Integer > 0)

Remarks:

1. Load sets must be selected in the Case Control Deck (LØAD=SID) to be used by NASTRAN.

2. If AXI=1, Y1 must be 0.0 or blank, and all data fields after Z1 must be 0.0 or blank. (Continuation card need not be present.)

3. CID must presently be 0 or blank.

4. Points 1 and 2, (X1, Y1, Z1) and (X2, Y2, Z2), must be distinct and must be equidistant from the center of the circle. Also, the center of the circle and the two points must be non-collinear.

5. The direction of current is assumed to be from point 1 to point 2.

6. These computations involve elliptic integrals computed by an iterative process with a default convergence criterion of 1.E-6. The criterion can be changed with a PARAM bulk data card. At most 15,000 iterations are performed. With these parameters, convergence will occur when an integration or grid point is no closer to the loop than an amount equal to 2% of the radius. A convergence criterion of 1.E-5 will allow the point to be much closer to the loop. If convergence fails, a message is output, and the computations continue with the last iterated value.

Input Data Card CFFREE - Free Fluid Surface

Description: Defines the fluid elements composing the free fluid surface in a hydroelastic analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CFFREE	EIDF	GRAVID	FACE		EIDF	GRAVID	FACE		
CFFREE	100	100	3		101	100	4		

Field	Contents
EIDF	Fluid element identification number (Integer > 0) (see Remark 1)
GRAVID	Identification number of a GRAV gravity vector set (Integer > 0)
FACE	Identification number of the face of the fliud element, EIDF, forming the free surface (0 < Integer ≤ 6) (see Remark 2)

Remarks:

1. Allowable fluid element types are CFHEX1, CFHEX2, CFTETRA and CFWEDGE.
2. The numbering conventions for solid faces are defined in fluid element connection bulk data card descriptions.

Input Data Card CFHEXi - Fluid Hexahedral Element Connection

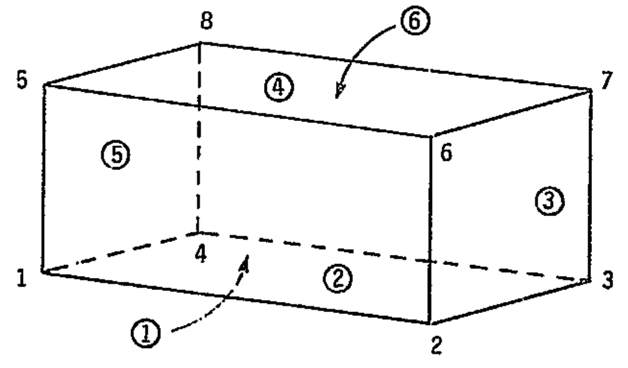
Description: Defines two types of fluid hexahedral elements (three-dimensional solids with eight vertices and six quadrilateral faces) to be used in hydroelastic analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CFHEXi	EID	MID	G1	G2	G3	G4	G5	G6	abc
CFHEX2	15	100	1	2	3	4	5	6	ABC

+bc	G7	G8							
+BC	7	8							

Field	Contents
CFHEXi	CFHEX1 or CFHEX2 (BCD) (see Remark 4)
EID	Element identification number (Integer > 0)
MID	Material identification number (Integer > 0)
G1,...,G8	Grid point identification numbers of connection points (Integer > 0, G1 ≠ G2 ≠ ... ≠ G8)



Remarks:

1. Element identification numbers must be unique with respect to all other element identification numbers.
2. The numbering and order of the grid points and faces, required for specifying free fluid surfaces, are defined in the figure above.
3. The quadrilateral faces must be nearly planar.
4. CFHEX1 is developed by 5 tetrahedra, CFHEX2 by 10 overlapping tetrahedra.
5. Material identification number must reference a MATF bulk data card.

Input Data Card CFLSTR - Fluid/Structure Interface

Description: Defines fluid/structure interfaces in hydroelastic analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CFLSTR	EIDF	GRAVID	EIDS1	EIDS2	EIDS3	EIDS4	EIDS5	EIDS6	abc
CFLSTR	100	10	1	2	11	12	21	22	ABC

+bc	EIDS7	EIDS8		etc.					dcf
+BC	31	32							

Alternate Form:

CFLSTR	EIDF	GRAVID	EID1	"THRU"	EID2				
CFLSTR	200	100	101	THRU	106				

Field	Contents
EIDF	Fluid element identification number (Integer > 0) (see Remark 3)
GRAVID	Identification number of a GRAV gravity vector set (Integer > 0)
EIDSi,EIDi	Structural element identification numbers (Integer > 0)

Remarks:

1. As many continuation cards as desired may appear when "THRU" is not used.
2. All element identification numbers between EID1 and EID2 must exist when using the "THRU" option.
3. Allowable fluid element types are CFHEX1, CFHEX2, CFTETRA and CFWEDGE.

Input Data Card CFLUIDi Fluid Element Connections

Description: Defines three types of fluid elements for axisymmetric fluid model.

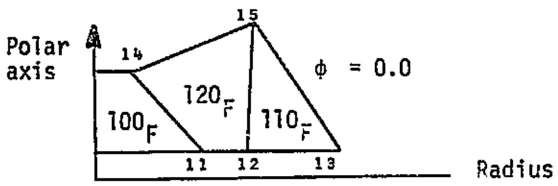
Format and Example:

1	2	3	4	5	6	7	8	9	10
CFLUID2	EID	IDF1	IDF2			RHØ	B		
CFLUID2	100	11	14			.025	0.0		
CFLUID3	EID	IDF1	IDF2	IDF3		RHØ	B		
CFLUID3	110	15	13	12		1.2			
CFLUID4	EID	IDF1	IDF2	IDF3	IDF4	RHØ	B		
CFLUID4	120	11	15	12	14				

Field	Contents
EID	Element identification number (Integer, $0 < Id_c < 10^5$)
IDFi	Identification number of RINGFL card (Integer > 0; IDF1 ≠ IDF2 ≠ IDF3 ≠ IDF4)
RHØ	Mass density (Real > 0.0 or blank; If blank, the AXIF default value is used)
B	Bulk modulus, pressure per volume ratio (Real or blank. Default value on AXIF card is used if blank)

Remarks:

1. This card is allowed only if an AXIF card is also present.
2. Element identification number must be unique with respect to <u>all</u> other fluid, scalar and structural elements.
3. The volume defined by IDFi is a body of revolution about the polar axis of the Fluid Coordinate System defined by AXIF. CFLUID2 defines a thick disk with IDF1 and IDF2 defining the outer corners as in the sketch.



4. All interior angles must be less than 180°.
5. The order of connected RINGFL points is arbitrary.
6. If the bulk modulus value is zero the fluid is assumed incompressible.

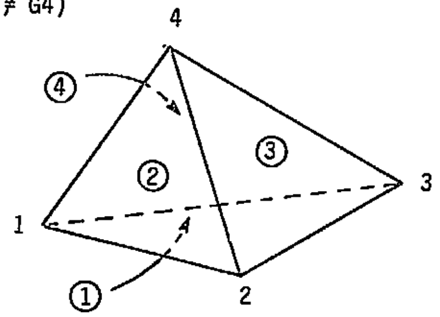
Input Data Card CFTETRA - Fluid Tetrahedral Element Connection

Description: Defines a fluid tetrahedral element (three-dimensional solid, with four vertices and four triangular faces) to be used in hydroelastic analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CFTETRA	EID	MID	G1	G2	G3	G4			
CFTETRA	25	6	1	2	3	4			

Field	Contents
EID	Element identification number (Integer > 0)
MID	Material identification number (Integer > 0)
G1,G2,G3,G4	Grid point identification numbers of connection points (Integer > 0, G1 ≠ G2 ≠ G3 ≠ G4)



Remarks:

1. Element identification numbers must be unique with respect to all other element identification numbers.

2. The numbering of the grid points and faces, required for specifying free fluid surfaces, are defined in the figure above.

3. Material identification number must reference a MATF bulk data card.

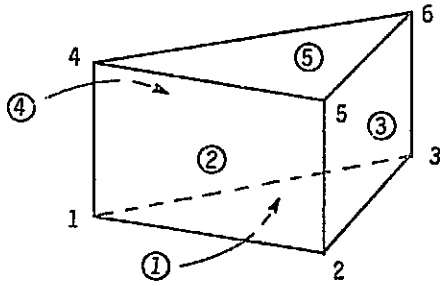
Input Data Card CFWEDGE - Fluid Wedge Element Connection

Description: Defines a fluid wedge element (three-dimensional solid, with three quadrilateral faces and two opposing triangular faces) to be used in hydroelastic analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CFWEDGE	EID	MID	G1	G2	G3	G4	G5	G6	
CFWEDGE	25	100	1	2	3	4	5	6	

Field	Contents
EID	Element identification number (Integer > 0)
MID	Material identification number (Integer > 0)
G1,...,G6	Grid point identification numbers of connection points (Integers > 0; G1 ≠ G2 ≠ ... ≠ G6)



Remarks:

1. Element identification numbers must be unique with respect to all other element identification numbers.

2. The numbering of the grid points and faces, required for specifying free fluid surfaces, are defined in the figure above.

3. The quadrilateral faces must be nearly planar.

4. Material identification number must reference a MATF bulk data card.

Input Data Card CHBDY Heat Boundary Element

Description: Defines a boundary element for heat transfer analysis which is used for heat flux, thermal vector flux, convection and/or radiation.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CHBDY	EID	PID	TYPE	G1	G2	G3	G4		
CHBDY	721	100	LINE	101	98				+BD721
+abc	GA1	GA2	GA3	GA4	V1	V2	V3		
+BD721	102	102			1.00	0.0	0.0		

Field	Contents
EID	Element identification number (Integer > 0)
PID	Property identification number (Integer > 0)
TYPE	Type of area involved (must be one of "PØINT", "LINE", "REV", "AREA3", "AREA4" or "ELCYL")
G1,G2,G3,G4	Grid point identification numbers of primary connected points (Integer > 0 or blank)
GA1,GA2,GA3,GA4	Grid or scalar point identification numbers of associated ambient points (Integer > 0 or blank)
V1,V2,V3	Vector (in the basic coordinate system) used for element orientation (real or blank)

Remarks:

1. The continuation card is not required.

2. The six types have the following characteristics:

   a. The "PØINT" type has one primary grid point, requires a property card, and the normal vector {V1,V2,V3} must be given if thermal vector flux is to be used.

   b. The "LINE" type has two primary grid points, requires a property card, and the vector is required if thermal vector flux is to be used.

   c. The "REV" type has two primary grid points which must lie in the x-z plane of the basic coordinate system with x > 0. The defined area is a conical section with z as the axis of symmetry. A property card is required for convection, radiation, or thermal vector flux.

   d. The "AREA3" and "AREA4" types have three and four primary grid points, respectively. These points define a triangular or quadrilateral surface and must be ordered to go around the boundary. A property card is required for convection, radiation, or thermal vector flux.

   e. The "ELCYL" type (elliptic cylinder) has two connected primary grid points, it requires a property card, and if thermal vector flux is used, the vector must be nonzero.

(Continued)

CHBDY (Cont.)

3. A property card, PHBDY, is used to define the associated area factors, the emissivity, the absorbtivity, and the principal radii of the elliptic cylinder. The material coefficients used for convection and thermal capacity are referenced by the PHBDY card. See this card description for details.

4. The associated points, GA1, GA2, etc., may be either grid or scalar points, and are used to define the fluid ambient temperature when a convection field exists. These points correspond to the primary (CHBDY element) points G1, G2, etc., and the number of them depends on the TYPE option, but they need not be unique. Their values may be set in statics with an SPC card, or they may be connected to other elements. If any field is blank, the ambient temperature associated with that grid point is assumed to be zero.

5. Heat flux may be applied to this element with QBDY1 or QBDY2 cards.

6. Thermal vector flux from a directional source may be applied to this element with a QVECT card. The orientation of the normal vector must be defined. The grid point ordering establishes the normal vector direction as end "a" to end "b" for line elements and "right hand rule" for cross product elements. See Section 1.8 for the definition of the normal vector for each element type.

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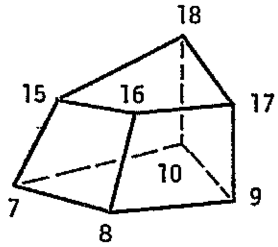
Input Data Card CHEXAi   Hexahedron Element Connection

Description: Defines two types of hexahedron elements (3 dimensional solid with 8 vertices and 6 quadrilateral faces, HEXAi) of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CHEXAi	EID	MID	G1	G2	G3	G4	G5	G6	abc
CHEXA2	15	2	7	8	9	10	15	16	ABC
+bc	G7	G8							
+BC	17	18							

Field	Contents
CHEXAi	CHEXA1 or CHEXA2 (see Remark 7)
EID	Element identification number (Integer > 0)
MID	Material identification number (Integer > 0)
G1,...,G8	Grid point identification numbers of connection points (Integers > 0, G1 ≠ G2 ≠ ... ≠ G8)



Remarks:
1. Element identification numbers must be unique with respect to all other element identification numbers.
2. The order at the grid points is: G1, G2, G3, G4 in order around one quadrilateral face. G5, G6, G7, G8 are in order in the same direction around the opposite quadrilateral, with G1 and G5 along the same edge.
3. The quadrilateral faces must be nearly planar.
4. There is no nonstructural mass.
5. For structural problems, material must be defined by MAT1 card.
6. Stresses are given in the basic coordinate system.
7. CHEXA1 represents the element as 5 tetrahedra, CHEXA2 represents the element as 10 overlapping tetrahedra.
8. For heat transfer problems, material may be defined with either a MAT4 or MAT5 card.

NASTRAN DATA DECK

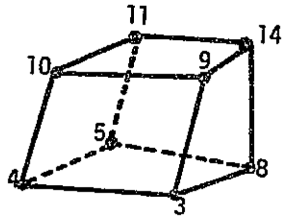
Input Data Card CIHEX1 — Linear Isoparametric Hexahedron Element Connection

Description: Defines a linear isoparametric hexahedron element of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CIHEX1	EID	PID	G1	G2	G3	G4	G5	G6	abc
CIHEX1	137	5	3	8	5	4	9	14	ABC
+bc	G7	G8							
+BC	11	10							

Field	Contents
EID	Element identification number (Integer > 0)
PID	Identification number of a PIHEX property card (Integer > 0)
G1,...,G8	Grid point identification numbers of connection points (Integer > 0, G1 ≠ G2 ≠ ... ≠ G8)



Remarks:

1. Element identification numbers must be unique with respect to all other element identification numbers.
2. Grid points G1, G2, G3, G4 must be given in counter-clockwise order about one quadrilateral face when viewed from inside the element. G5, G6, G7, G8 are in order in the same direction around the opposite quadrilateral, with G1 and G5 along the same edge.
3. There is no non-structural mass.
4. The quadrilateral faces need not be planar.
5. Stresses are given in the basic coordinate system.

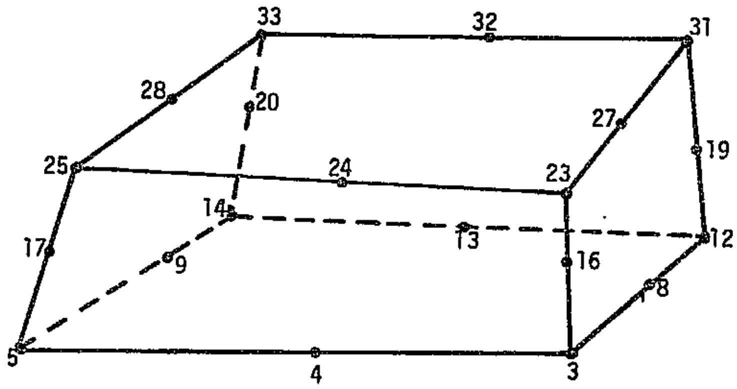
Input Data Card CIHEX2 Quadratic Isoparametric Hexahedron Element Connection

Description: Defines a quadratic isoparametric hexahedron element of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CIHEX2	EID	PID	G1	G2	G3	G4	G5	G6	abc
CIHEX2	110	7	3	8	12	13	14	9	ABC
+bc	G7	G8	G9	G10	G11	G12	G13	G14	def
+BC	5	4	16	19	20	17	23	27	DEF
+ef	G15	G16	G17	G18	G19	G20			
+EF	31	32	33	28	25	24			

Field	Contents
EID	Element identification number (Integer > 0)
PID	Identification number of a PIHEX property card (Integer > 0)
G1,...,G20	Grid point identification numbers of connection points (Integer > 0, G1 ≠ G2 ≠ ... ≠ G20)



Remarks:
1. Element identification numbers must be unique with respect to all other element identification numbers.
2. Grid points G1,...,G8 must be given in counter-clockwise order about one quadrilateral face when viewed from inside the element. G9,...,G12 and G13,...,G20 are in the same direction with G1, G9 and G13 along the same edge.
3. There is no nonstructural mass.
4. The quadrilateral faces need not be planar.
5. Stresses are given in the basic coordinate system.

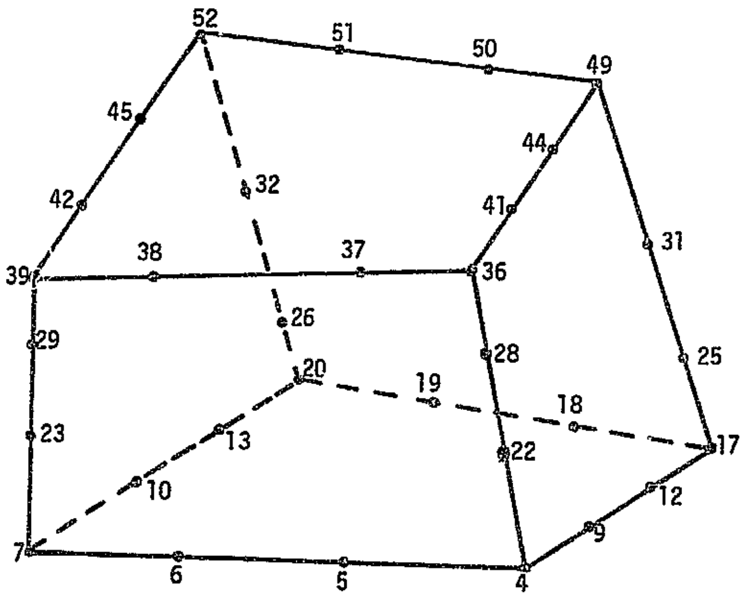
Input Data Card CIHEX3 Cubic Isoparametric Hexahedron Element Connection

Description: Defines a cubic isoparametric hexahedron element of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CIHEX3	EID	PID	G1	G2	G3	G4	G5	G6	abc
CIHEX3	15	3	4	9	12	17	18	19	ABC
+bc	G7	G8	G9	G10	G11	G12	G13	G14	def
+BC	20	13	10	7	6	5	22	25	DEF
+ef	G15	G16	G17	G18	G19	G20	G21	G22	ghi
+EF	26	23	28	31	32	29	36	41	GHI
+hi	G23	G24	G25	G26	G27	G28	G29	G30	jkl
+HI	44	49	50	51	52	45	42	39	JKL
+kl	G31	G32							
+KL	38	37							

Field	Contents
EID	Element identification number (Integer > 0)
PID	Identification number of a PIHEX property card (Integer > 0)
G1,...,G32	Grid point identification number of connection points (Integer > 0, G1 ≠ G2 ≠ ... ≠ G32)



(Continued)

CIHEX3 (Cont.)

Remarks: 1. Element identification numbers must be unique with respect to all other element identification numbers.

2. Grid points G1,...,G12 must be given in counter-clockwise order about one quadrilateral face when viewed from inside the element. G13,...,G16; G17,...,G20; and G21,...,G32 are in the same direction with G1, G13, G17, G21 along the same edge.

3. There is no nonstructural mass.

4. The quadrilateral faces need not be planar.

5. Stresses are given in the basic coordinate system.

Input Data Card CIS2D8 - Quadratic Isoparametric Element Connection

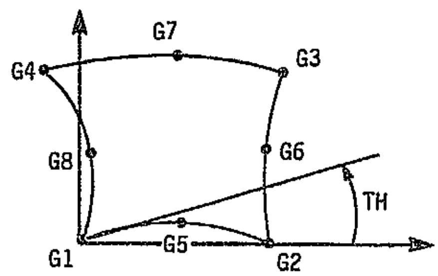
Description: Defines a quadriparabolic isoparametric membrane element (IS2D8) of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CIS2D8	EID	PID	G1	G2	G3	G4	G5	G6	+abc
CIS2D8	16	2	12	10	15	18	22	3	+ABC

+abc	G7	G8	ID1	TH					
+ABC	7	11							

Field	Contents
EID	Element identification number (Integer > 0)
PID	Identification number of a PIS2D8 property card (Integer > 0)
G1,G2,...,G8	Grid point identification numbers of connection points (Integers > 0; G1 thru G8 must be unique)
ID1	Number of Gauss quadrature points (ID1=2 or 3--default is 2)
TH	Material property orientation angle in degrees (Real). The sketch below gives the sign convention for TH.



Remarks:

1. Element identification numbers must be unique with respect to all other element identification numbers.
2. Grid points G1 thru G8 must be ordered as shown above.
3. This element is a planar element, i.e., G1 thru G8 must be in a plane.
4. Stresses are computed in the element coordinate system.
5. The element may be collapsed to a triangle by having coincident grid points or by making two edges collinear (which is the preferred method). If grid points are made

(Continued)

CIS2D8 (Cont.)

coincident, the only choices are G2, G6 and G3 or G3, G4 and G7. Grid points G1, G5 and G2 may not be coincident, nor may grid points G1, G8 and G4.

6. The midpoints G5, G6, G7 and G8 should be placed as close to the mid-side as possible, except for unusual circumstances, e.g., when the element is to be used as a crack element.

NASTRAN DATA DECK

Input Data Card CMASS1 Scalar Mass Connection

Description: Defines a scalar mass element of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CMASS1	EID	PID	G1	C1	G2	C2			
CMASS1	32	6	2	1	2	3			

Field	Contents
EID	Unique element identification number (Integer > 0)
PID	Identification number of a PMASS property card (Default is EID) (Integer > 0)
G1, G2	Geometric grid point identification number (Integer ≥ 0)
C1, C2	Component number (6 ≥ Integer ≥ 0)

Remarks:

1. Scalar points may be used for G1 and/or G2 in which case the corresponding C1 and/or C2 must be zero or blank. Zero or blank may be used to indicate a grounded* terminal G1 or G2 with a corresponding blank or zero C1 or C2. If only scalar points and/or ground are involved, it is more efficient to use the CMASS3 card.

2. Element identification numbers must be unique with respect to all other element identification numbers.

3. The two connection points, (G1, C1) and (G2, C2), must be distinct.

4. For a discussion of the scalar elements, see Section 5.6 of the Theoretical Manual.

* A grounded terminal is a scalar point or coordinate of a geometric grid point whose displacement is constrained to zero.

Input Data Card CMASS2 Scalar Mass Property and Connection

Description: Defines a scalar mass element of the structural model without reference to a property value.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CMASS2	EID	M	G1	C1	G2	C2			
CMASS2	32	9.25	6	1	7				

Field	Contents
EID	Unique element identification number (Integer > 0)
M	The value of the scalar mass (Real)
G1, G2	Geometric grid point identification number (Integer $\geq$ 0)
C1, C2	Component number (6 $\geq$ Integer $\geq$ 0)

Remarks:
1. Scalar points may be used for G1 and/or G2 in which case the corresponding C1 and/or C2 must be zero or blank. Zero or blank may be used to indicate a grounded* terminal G1 or G2 with a corresponding blank or zero C1 or C2. If only scalar points and/or ground are involved, it is more efficient to use the CMASS4 card.
2. Element identification numbers must be unique with respect to all other element identification numbers.
3. This card completely defines the element since no material or geometric properties are required.
4. The two connection points, (G1, C1) and (G2, C2), must be distinct.
5. For a discussion of the scalar elements, see Section 5.6 of the Theoretical Manual.

* A grounded terminal is a scalar point or coordinate of a geometric grid point whose displacement is constrained to zero.

NASTRAN DATA DECK

Input Data Card CMASS3 Scalar Mass Connection

Description: Defines a scalar mass element of the structural model which is connected only to scalar points.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CMASS3	EID	PID	S1	S2	EID	PID	S1	S2	
CMASS3	13	42	62	1					

Field	Contents
EID	Unique element identification number (Integer > 0)
PID	Identification number of a PMASS property card (Default is EID) (Integer > 0)
S1, S2	Scalar point identification numbers (Integer $\geq$ 0; S1 $\neq$ S2)

Remarks: 1. S1 or S2 may be blank or zero indicating a constrained coordinate.

2. Element identification numbers must be unique with respect to all other element identification numbers.

3. One or two scalar masses may be defined on a single card.

4. For a discussion of the scalar elements, see Section 5.6 of the Theoretical Manual.

Input Data Card CMASS4 Scalar Mass Property and Connection

Description: Defines a scalar mass element of the structural model which is connected only to scalar points without reference to a property value.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CMASS4	EID	M	S1	S2	EID	M	S1	S2	
CMASS4	23	14.92	6	23	2	-16.3	0	29	

Field	Contents
EID	Unique element identification number (Integer > 0)
M	The scalar mass value (Real)
S1, S2	Scalar point identification numbers (Integer $\geq$ 0; S1 $\neq$ S2)

Remarks:

1. S1 or S2 may be blank or zero indicating a constrained coordinate.
2. Element identification numbers must be unique with respect to all other element identification numbers.
3. This card completely defines the element since no material or geometric properties are required.
4. One or two scalar masses may be defined on a single card.
5. For a discussion of the scalar elements, see Section 5.6 of the Theoretical Manual.

Input Data Card CNGRNT Identical (Congruent) Elements Indicator

Description: Designates secondary element(s) identical (or congruent) to a primary element.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CNGRNT	PRID	SECID1	SECID2	SECID3	SECID4	SECID5	SECID6	SECID7	abc
CNGRNT	11	2	17	34	35	36			

+bc	SECID8	SECID9		-etc.-					

Alternate Form

CNGRNT	PRID	SECID1	"THRU"	SECID2					
CNGRNT	7	10	THRU	55					

Field	Contents
PRID	Identification number of the primary element (not necessarily the lowest number)
SECIDi	Identification number(s) of secondary element(s) whose matrices will be identical (or congruent) to those of the primary element.

Remarks:

1. Orientation, geometry, etc. must be truly identical such that the same stiffness, mass and damping matrices are generated in the global coordinate system.
2. This feature is automatically used by the INPUT module.
3. The CNGRNT feature cannot be used when an AXIC card is present in the Bulk Data Deck.
4. An element that has been listed as a primary ID on a CNGRNT card cannot be listed as a secondary ID on another CNGRNT card. However, if the element is listed as a secondary ID on the same card, then such secondary IDs are ignored.
5. The same secondary IDs cannot be listed as congruent to two or more different primary IDs.
6. Redundant specifications on CNGRNT cards are ignored.
7. The element IDs (primary or secondary) specified on a CNGRNT card need not all exist in a model. This greatly facilitates the use of the THRU option on the card. However, the user should be cautioned that, if too many non-existent elements are specified in the CNGRNT data (as may be the case when the THRU option is used), the EMG (Element Matrix Generator) module may not have enough core to process all the CNGRNT data. In that case, an appropriate message is issued and those elements whose CNGRNT data cannot be processed will have their element matrices computed separately.

(Continued)

CNGRNT (Cont.)

8. The stiffness, mass and damping matrices are actually calculated for the lowest numbered element in the congruent set (even through this element may not be the primary ID).

9. See Section 1.14 for a detailed discussion of the congruent feature.

Input Data Card <u>CØNCT</u> Substructure Connectivity

<u>Description</u>: Defines the grid point and degree of freedom connectivities between two substructures for a manual CØMBINE operation.

<u>Format and Example</u>:

1	2	3	4	5	6	7	8	9	10
CØNCT	SID	C	SUBA	SUBB					def
CØNCT	307	1236	WINGRT	FUSELAGE					DEF
+ef	GA1	GB1	GA2	GB2	GA3	GB3	GA4	GB4	hij
+EF	201	207	958	214	971	216	982		HIJ

<u>Field</u> <u>Contents</u>

SID Identification number of connectivity set (Integer > 0)

C Component number - Any unique combination of the digits 1 - 6 (with no imbedded blanks) when the Gi are grid points, or null if they are scalar points.

SUBA, SUBB Names of basic substructures being connected (BCD).

GAi, GBi Grid or scalar point identification numbers GAi from SUBA connects to GBi from SUBB by the degrees of freedom specified in C (Integer > 0)

<u>Remarks</u>: 1. At least one continuation card must be present.

2. Components specified on a CØNCT card <u>will</u> be overridden by RELES cards.

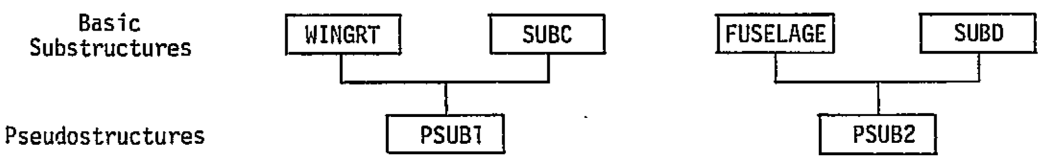
3. Several CØNCT and CØNCT1 cards may be input with the same value of SID.

4. An alternate format is given by the CØNCT1 data card.

5. Connectivity sets must be selected in the Substructure Control Deck (CØNNECT=SID) to be used by NASTRAN. Note that 'CØNNECT' is a subcommand of the substructure CØMBINE command.

6. SUBA and SUBB must be component basic substructures of the pseudostructures being combined as specified on the substructure CØMBINE command card. SUBA and SUBB must <u>not</u> be components of the same pseudostructure.

In the figure below, a substructure "tree" and a set of substructure command cards are shown. The CØNNECT subcommand references the example CØNCT card above. In this example, pseudostructure PSUB1 and PSUB2 are combined and connected only at points in their respective basic component substructures WINGRT and FUSELAGE.



(Continued)

CØNCT (Cont.)

```
COMBINE(MANUAL) PSUB1,PSUB2
      NAME = PPSUB
      TØLER = 0.01
      CØNNECT = 307
```

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Input Data Card CØNCT1 Substructure Connectivity

Description: Defines the grid point and degree of freedom connectivities between two or more substructures for a manual CØMBINE operation.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CØNCT1	SID	NAME1	NAME2	NAME3	NAME4	NAME5	NAME6	NAME7	def
CØNCT1	805	WINGRT	FUSELAGE	MIDWG	PØD				DEF
+ef	C1	G11	G12	G13	G14	G15	G16	G17	hij
+EF	123	528	17	32	106				HIJ
+ij	C2	G21	G22	G23	G24	G25	G26	G27	
+IJ	46	518							etc.

Field	Contents
SID	Identification number of connectivity set (Integer > 0)
NAMEi	Basic substructure name (BCD)
Ci	Component number - Any unique combination of the digits 1 - 6 (with no imbedded blanks) when the Gi are grid points, or null if they are scalar points.
Gij	Grid or scalar point identification number in substructure namej with components Ci (Integer > 0)

Remarks:
1. At least one continuation card must be present.
2. Components specified on CØNCT1 card will not be overridden by RELES cards.
3. Several CØNCT and CØNCT1 cards may be input with the same value of SID.
4. An alternate format is given by the CØNCT card.
5. Connectivity sets must be selected in the Substructure Control Deck (CØNNECT=SID) to be used by NASTRAN. Note that 'CØNNECT' is a subcommand of the substructure CØMBINE command.
6. The NAMEi's must be the names of basic substructure components of the pseudostructures named on the CØMBINE card in the Substructure Control Deck. See the CØNCT card for a more complete discussion related to the combination of two substructures.
7. This card and its continuations effectively describe a map of connectivities. Grid points entered in the corresponding field of a substructure name define the connectivity participation for that substructure. Each continuation card defines the connection relationships among the participating substructures for the components entered.

Input Data Card CØNM1 Concentrated Mass Element Connection

Description: Defines a 6x6 symmetric mass matrix at a geometric grid point of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CØNM1	EID	G	CID	M11	M21	M22	M31	M32	abc
CØNM1	2	22	2	2.9		6.3			+1
+bc	M33	M41	M42	M43	M44	M51	M52	M53	def
+1	4.8				28.6				+2
+ef	M54	M55	M61	M62	M63	M64	M65	M66	
+2		28.6						28.6	

Field	Contents
EID	Unique element identification number (Integer > 0)
G	Grid point identification number (Integer > 0)
CID	Coordinate system identification number for the mass matrix (Integer $\geq$ 0)
Mij	Mass matrix values (Real)

Remarks: 1. For a less general means of defining concentrated mass at grid points, see CØNM2.

2. Element identification numbers must be unique with respect to all other element identification numbers.

Input Data Card CØNM2 Concentrated Mass Element Connection

Description: Defines a concentrated mass at a grid point of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CØNM2	EID	G	CID	M	X1	X2	X3		abc
CØNM2	2	15	6	49.7					123
+bc	I11	I21	I22	I31	I32	I33			
+23	16.2		16.2			7.8			

Field	Contents
EID	Element identification number (Integer > 0)
G	Grid point identification number (Integer >0)
CID	Coordinate system identification number (Integer $\geq$ 0)
M	Mass Value (Real)
X1,X2,X3	Offset distances for the mass in the coordinate system defined in field 4 (Real)
Iij	Mass moments of inertia measured at the mass c.g. in coordinate system defined by field 4 (Real)

Remarks:

1. Element identification numbers must be unique with respect to all other element identification numbers.
2. For a more general means of defining concentrated mass at grid points, see CØNM1.
3. The continuation card may be omitted.
4. The form of the inertia matrix about its c.g. is taken as:

$$\begin{bmatrix} M & & & 0 & zM & -yM \\ & M & & -zM & 0 & xM \\ & & M & yM & -xM & 0 \\ & & & I11 & -I21 & -I31 \\ & \text{SYM.} & & & I22 & -I32 \\ & & & & & I33 \end{bmatrix}$$

Input Data Card CØNRØD Rod Element Property and Connection

Description: Defines a rod element of the structural model without reference to a property card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CØNRØD	EID	G1	G2	MID	A	J	C	NSM	
CØNRØD	2	16	17	23	2.69				

Field	Contents
EID	Unique element identification number (Integer > 0)
G1, G2	Grid point identification numbers of connection points (Integer > 0; G1 $\neq$ G2)
MID	Material identification number (Integer > 0)
A	Area of rod (Real)
J	Torsional constant (Real)
C	Coefficient for torsional stress determination (Real)
NSM	Nonstructural mass per unit length (Real)

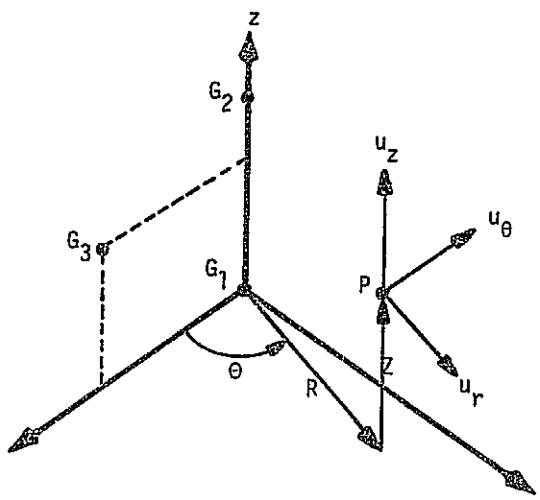
Remarks: 1. Element identification numbers must be unique with respect to all other element identification numbers.

2. For structural problems, CØNRØD cards may only reference MAT1 material cards.

3. For heat transfer problems, CØNRØD cards may only reference MAT4 or MAT5 material cards.

Input Data Card CØRD1C   Cylindrical Coordinate System Definition

Description: Defines a cylindrical coordinate system by reference to three grid points. These points must be defined in coordinate systems whose definition does not involve the coordinate system being defined. The first point is the origin, the second lies on the z-axis, and the third lies in the plane of the azimuthal origin.



Format and Example:

1	2	3	4	5	6	7	8	9	10
CØRD1C	CID	G1	G2	G3	CID	G1	G2	G3	
CØRD1C	3	16	32	19					

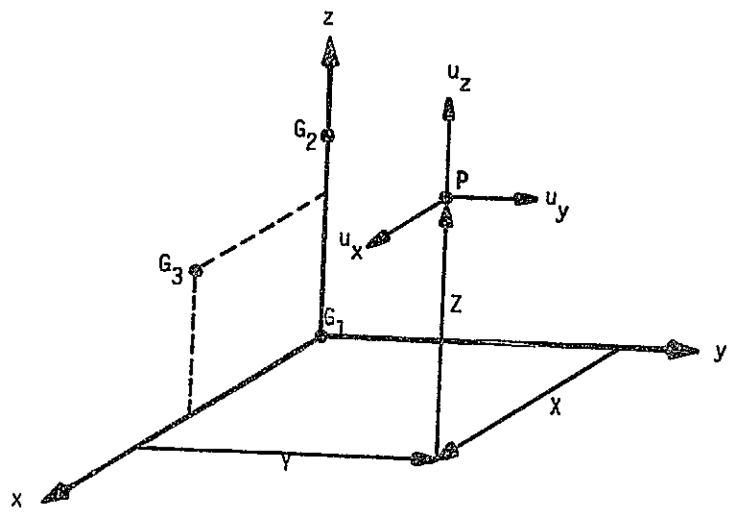
Field	Contents
CID	Coordinate system identification number (Integer > 0)
G1, G2, G3	Grid point identification numbers (Integer > 0; G1 ≠ G2 ≠ G3)

Remarks:
1. Coordinate system identification numbers on all CØRD1R, CØRD1C, CØRD1S, CØRD2R, CØRD2C, and CØRD2S cards must all be unique.
2. The three points G1, G2, G3 must be noncollinear.
3. The location of a grid point (P in the sketch) in this coordinate system is given by (R, Θ, Z) where Θ is measured in degrees.
4. The displacement coordinate directions at P are dependent on the location of P as shown above by (u_r, u_θ, u_z).
5. Points on the z-axis may not have their displacement directions defined in this coordinate system since an ambiguity results.
6. One or two coordinate systems may be defined on a single card.

BULK DATA DECK

Input Data Card CØRD1R Rectangular Coordinate System Definition

Description: Defines a rectangular coordinate system by reference to three grid points. These points must be defined in coordinate systems whose definition does not involve the coordinate system being defined. The first point is the origin, the second lies on the z-axis, and the third lies in the x-z plane.



Format and Example:

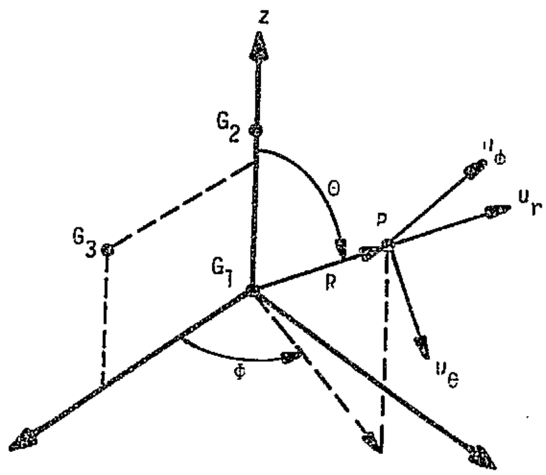
1	2	3	4	5	6	7	8	9	10
CØRD1R	CID	G1	G2	G3	CID	G1	G2	G3	
CØRD1R	3	16	32	19					

Field	Contents
CID	Coordinate system identification number (Integer > 0)
G1, G2, G3	Grid point identification numbers (Integer > 0; G1 ≠ G2 ≠ G3)

Remarks:
1. Coordinate system identification numbers on all CØRD1R, CØRD1C, CØRD1S, CØRD2R, CØRD2C, and CØRD2S cards must all be unique.
2. The three points G1, G2, G3 must be noncollinear.
3. The location of a grid point (P in the sketch) in this coordinate system is given by (X, Y, Z).
4. The displacement coordinate directions at P are shown above by (u_x, u_y, u_z).
5. One or two coordinate systems may be defined on a single card.

Input Data Card CØRD1S   Spherical Coordinate System Definition

Description: Defines a spherical coordinate system by reference to three grid points. These points must be defined in coordinate systems whose definition does not involve the coordinate system being defined. The first point is the origin, the second lies on the z-axis, and the third lies in the plane of the azimuthal origin.



Format and Example:

1	2	3	4	5	6	7	8	9	10
CØRD1S	CID	G1	G2	G3	CID	G1	G2	G3	
CØRD1S	3	16	32	19					

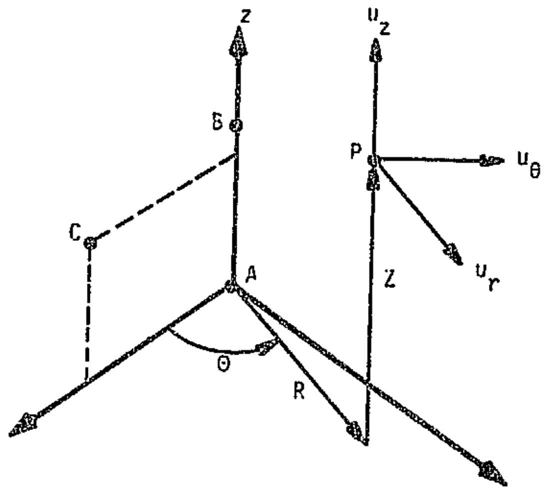
Field	Contents
CID	Coordinate system identification number (Integer > 0)
G1, G2, G3	Grid point identification numbers (Integer > 0; G1 ≠ G2 ≠ G3)

Remarks:
1. Coordinate system identification numbers on all CØRD1R, CØRD1C, CØRD1S, CØRD2R, CØRD2C, and CØRD2S cards must all be unique.
2. The three points G1, G2, G3 must be noncollinear.
3. The location of a grid point (P in the sketch) in this coordinate system is given by (R, Θ, Φ) where Θ and Φ are measured in degrees.
4. The displacement coordinate directions at P are dependent on the location of P as shown above by (u_r, u_θ, u_ϕ).
5. Points on the polar axis may not have their displacement directions defined in this coordinate system since an ambiguity results.
6. One or two coordinate systems may be defined on a single card.

BULK DATA DECK

Input Data Card CØRD2C Cylindrical Coordinate System Definition

Description: Defines a cylindrical coordinate system by reference to the coordinates of three points. The first point defines the origin. The second point defines the direction of the z-axis. The third lies in the plane of the azimuthal origin. The reference coordinate must be independently defined.



Format and Example:

1	2	3	4	5	6	7	8	9	10
CØRD2C	CID	RID	A1	A2	A3	B1	B2	B3	ABC
CØRD2C	3	17	-2.9	1.0	0.0	3.6	0.0	1.0	123
+BC	C1	C2	C3						
+23	5.2	1.0	-2.9						

Field	Contents
CID	Coordinate system identification number (Integer > 0)
RID	Reference to a coordinate system which is defined independently of new coordinate system (Integer ≥ 0 or blank)
A1,A2,A3 B1,B2,B3 C1,C2,C3	Coordinates of three points in coordinate system defined in field 3 (Real)

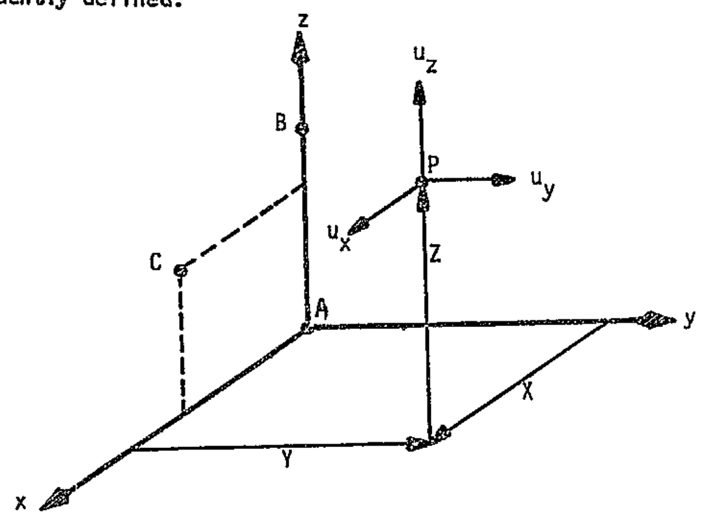
(Continued)

CØRD2C (Cont.)

Remarks:
1. Continuation card must be present.
2. The three points (A1, A2, A3), (B1, B2, B3), (C1, C2, C3) must be unique and noncollinear. Noncollinearity is checked by the geometry processor.
3. Coordinate system identification numbers on all CØRD1R, CØRD1C, CØRD1S, CØRD2R, CØRD2C, and CØRD2S cards must all be unique.
4. An RID of zero references the basic coordinate system.
5. The location of a grid point (P in the sketch) in this coordinate system is given by (R, Θ, Z) where Θ is measured in degrees.
6. The displacement coordinate directions at P are dependent on the location of P as shown above by (u_r, u_θ, u_z).
7. Points on the z-axis may not have their displacement direction defined in this coordinate system since an ambiguity results.

Input Data Card CØRD2R Rectangular Coordinate System Definition

Description: Defines a rectangular coordinate system by reference to the coordinates of three points. The first point defines the origin. The second point defines the direction of the z-axis. The third point defines a vector which, with the z-axis, defines the x-z plane. The reference coordinate must be independently defined.



Format and Example:

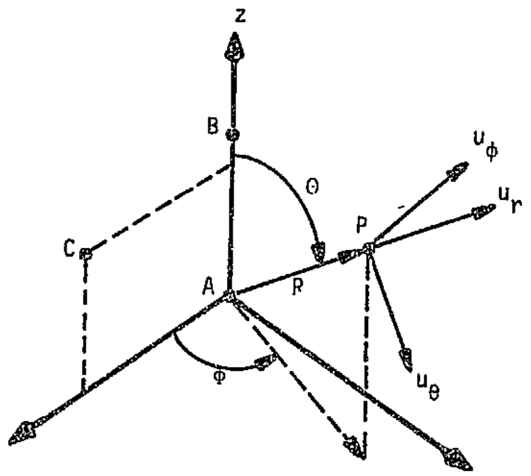
1	2	3	4	5	6	7	8	9	10
CØRD2R	CID	RID	A1	A2	A3	B1	B2	B3	ABC
CØRD2R	3	17	-2.9	1.0	0.0	3.6	0.0	1.0	123
+BC	C1	C2	C3						
+23	5.2	1.0	-2.9						

Field	Contents
CID	Coordinate system identification number (Integer > 0)
RID	Reference to a coordinate system which is defined independently of new coordinate system (Integer ≥ 0 or blank)
A1,A2,A3 B1,B2,B3 C1,C2,C3	Coordinates of three points in coordinate system defined in field 3 (Real)

Remarks:
1. Continuation card must be present.
2. The three points (A1, A2, A3), (B1, B2, B3), (C1, C2, C3) must be unique and non-collinear. Noncollinearity is checked by the geometry processor.
3. Coordinate system identification numbers on all CØRD1R, CØRD1C, CØRD1S, CØRD2R, CØRD2C, and CØRD2S cards must all be unique.
4. An RID of zero references the basic coordinate system.
5. The location of a grid point (P in the sketch) in this coordinate system is given by (X, Y, Z).
6. The displacement coordinate directions at P are shown by (u_x, u_y, u_z).

Input Data Card CØRD2S   Spherical Coordinate System Definition

Description: Defines a spherical coordinate system by reference to the coordinates of three points. The first point defines the origin. The second point defines the direction of the z-axis. The third lies in the plane of the azimuthal origin. The reference coordinate must be independently defined.



Format and Example:

1	2	3	4	5	6	7	8	9	10
CØRD2S	CID	RID	A1	A2	A3	B1	B2	B3	ABC
CØRD2S	3	17	-2.9	1.0	0.0	3.6	0.0	1.0	123
+BC	C1	C2	C3						
+23	5.2	1.0	-2.9						

Field	Contents
CID	Coordinate system identification number (Integer > 0)
RID	Reference to a coordinate system which is defined independently of new coordinate system (Integer ≥ 0 or blank)
A1,A2,A3 B1,B2,B3 C1,C2,C3	Coordinates of three points in coordinate system defined in field 3 (Real)

(Continued)

CØRD2S (Cont.)

Remarks:

1. Continuation card must be present.

2. The three points (A1, A2, A3), (B1, B2, B3), (C1, C2, C3) must be unique and non-collinear. Noncollinearity is checked by the geometry processor.

3. Coordinate system identification numbers on all CØRD1R, CØRD1C, CØRD1S, CØRD2R, CØRD2C, and CØRD2S cards must all be unique.

4. An RID of zero references the basic coordinate system.

5. The location of a grid point (P in the sketch) in this coordinate system is given by (R, Θ, Φ) where Θ and Φ are measured in degrees.

6. The displacement coordinate directions at P are shown above by (u_r, u_θ, u_ϕ).

7. Points on the polar axis may not have their displacement directions defined in this coordinate system since an ambiguity results.

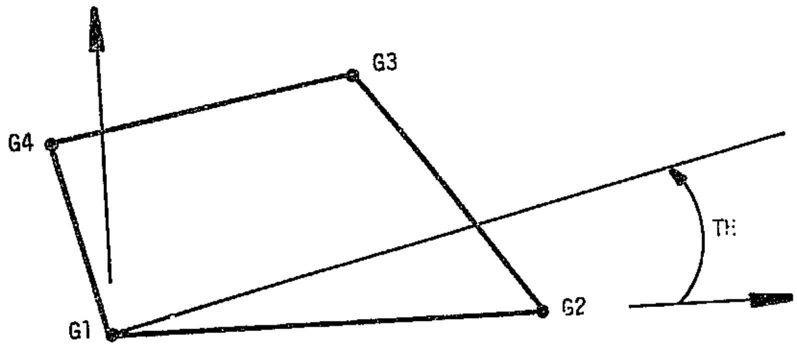
Input Data Card CQDMEM Quadrilateral Element Connection

Description: Defines a quadrilateral membrane element (QDMEM) of the structural model consisting of four overlapping TRMEM elements.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CQDMEM	EID	PID	G1	G2	G3	G4	TH		
CQDMEM	72	13	13	14	15	16	29.2		

Field	Contents
EID	Element identification number (Integer > 0)
PID	Identification number of a PQDMEM property card (Default is EID) (Integer > 0)
G1,G2,G3,G4	Grid point identification numbers of connection points (Integer > 0; G1 ≠ G2 ≠ G3 ≠ G4)
TH	Material property orientation angle in degrees (Real) The sketch below gives the sign convention for TH.



Remarks:
1. Element identification numbers must be unique with respect to all other element identification numbers.
2. Grid points G1 thru G4 must be ordered consecutively around the perimeter of the element.
3. All interior angles must be less than 180°.

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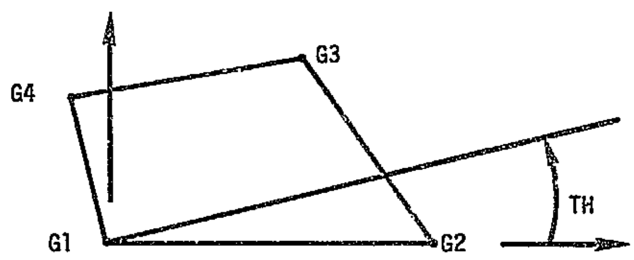
Input Data Card CQDMEM1 Isoparametric Quadrilateral Element Connection

Description: Defines an isoparametric quadrilateral membrane element (QDMEM1) of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CQDMEM1	EID	PID	G1	G2	G3	G4	TH		
CQDMEM1	72	13	13	14	15	16	29.2		

Field	Contents
EID	Element identification number (Integer > 0)
PID	Identification number of a PQDMEM1 property card (Default is EID) (Integer > 0)
G1,G2,G3,G4	Grid point identification numbers of connection points (Integer > 0); G1 ≠ G2 ≠ G3 ≠ G4)
TH	Material property orientation angle in degrees (Real) The sketch below gives the sign convention for TH



Remarks: 1. Element identification numbers must be unique with respect to all other element identification numbers.

2. Grid points G1 through G4 must be ordered consecutively around the perimeter of the element.

3. All interior angles must be less than 180 degrees.

4. In a HEAT formulation, element type CQDMEM1 is automatically replaced by element type CQDMEM.

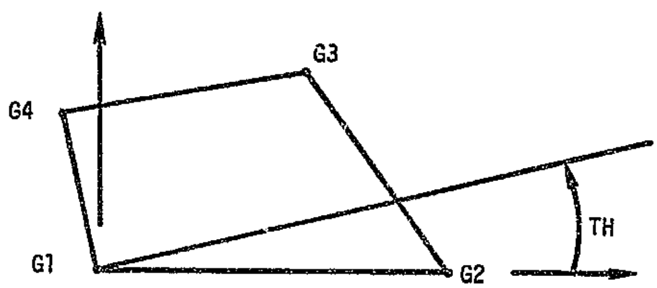
Input Data Card CQDMEM2 Quadrilateral Element Connection

Description: Defines a quadrilateral membrane element (QDMEM2) of the structural model consisting of four nonoverlapping TRMEM elements.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CQDMEM2	EID	PID	G1	G2	G3	G4	TH		
CQDMEM2	72	13	13	14	15	16	29.2		

Field	Contents
EID	Element identification number (Integer > 0)
PID	Identification number of a PQDMEM2 property card (Default is EID) (Integer > 0)
G1,G2,G3,G4	Grid point identification numbers of connection points (Integer > 0; G1 ≠ G2 ≠ G3 ≠ G4)
TH	Material property orientation angle in degrees (Real) The sketch below gives the sign convention for TH



Remarks:
1. Element identification numbers must be unique with respect to all other element identification numbers.
2. Grid points G1 through G4 must be ordered consecutively around the perimeter of the element.
3. All interior angles must be less than 180 degrees.
4. In a HEAT formulation, element type CQDMEM2 is automatically replaced by element type CQDMEM.

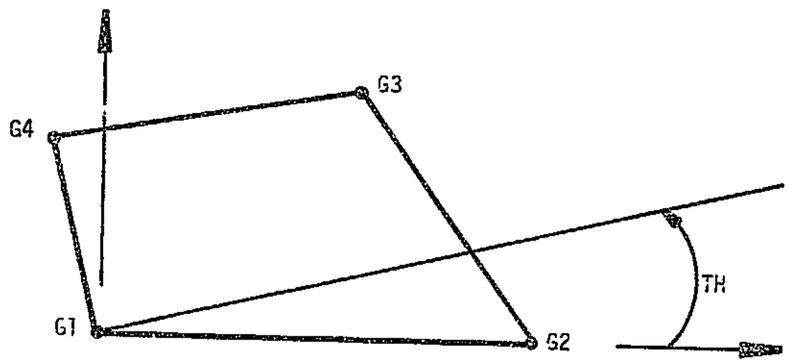
Input Data Card CQDPLT   Quadrilateral Element Connection

Description: Defines a quadrilateral bending element (QDPLT) of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CQDPLT	EID	PID	G1	G2	G3	G4	TH		
CQDPLT	72	13	13	14	15	16	29.2		

Field	Contents
EID	Element identification number (Integer > 0)
PID	Identification number of a PQDPLT property card (Default is EID) (Integer > 0)
G1,G2,G3,G4	Grid point identification numbers of connection points (Integer > 0; G1 ≠ G2 ≠ G3 ≠ G4)
TH	Material property orientation angle in degrees (Real) The sketch below gives the sign convention for TH.



Remarks:
1. Element identification numbers must be unique with respect to all other element identification numbers.
2. Grid points G1 thru G4 must be ordered consecutively around the perimeter of the element.
3. All interior angles must be less than 180°.
4. No structural mass is generated by this element.

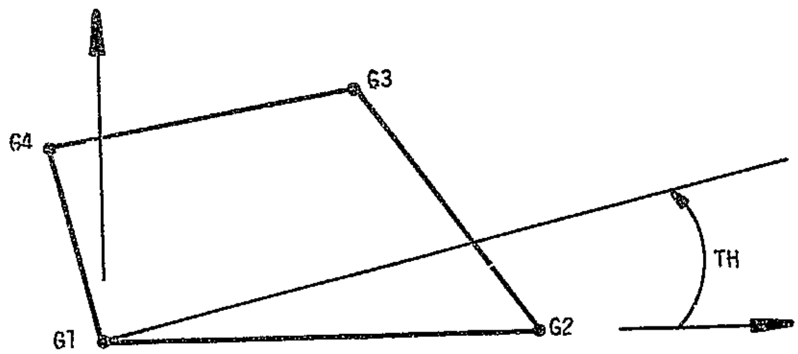
Input Data Card CQUAD1 Quadrilateral Element Connection

Description: Defines a quadrilateral membrane and bending element (QUAD1) of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CQUAD1	EID	PID	G1	G2	G3	G4	TH		
CQUAD1	72	13	13	14	15	16	29.2		

Field	Contents
EID	Element identification number (Integer > 0)
PID	Identification number of a PQUAD1 property card (Default is EID) (Integer > 0)
G1,G2,G3,G4	Grid point identification numbers of connection points (Integer > 0; G1 ≠ G2 ≠ G3 ≠ G4)
TH	Material property orientation angle in degrees (Real) The sketch below gives the sign convention for TH.



Remarks:

1. Element identification numbers must be unique with respect to all other element identification numbers.
2. Grid points G1 thru G4 must be ordered consecutively around the perimeter of the element.
3. All interior angles must be less than 180°.

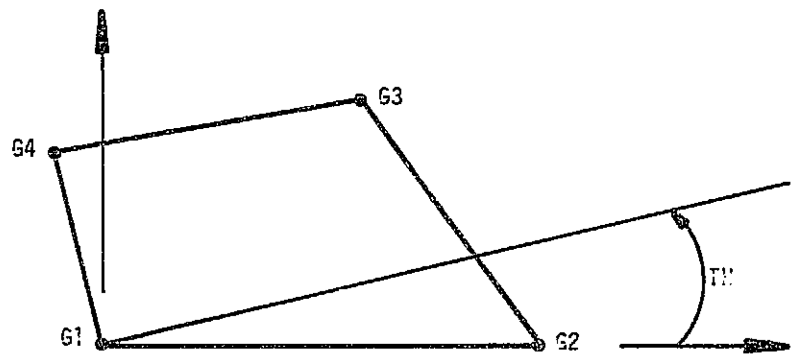
Input Data Card CQUAD2 Quadrilateral Element Connection

Description: Defines a homogeneous quadrilateral membrane and bending element (QUAD2) of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CQUAD2	EID	PID	G1	G2	G3	G4	TH		
CQUAD2	72	13	13	14	15	16	29.2		

Field	Contents
EID	Element identification number (Integer > 0)
PID	Identification number of a PQUAD2 property card (Default is EID) (Integer > 0)
G1,G2,G3,G4	Grid point identification numbers of connection points (Integer > 0; G1 ≠ G2 ≠ G3 ≠ G4)
TH	Material property orientation angle in degrees (Real) The sketch below gives the sign convention for TH.



Remarks: 1. Element identification numbers must be unique with respect to all other element identification numbers.

2. Grid points G1 thru G4 must be ordered consecutively around the perimeter of the element.

3. All interior angles must be less than 180°.

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Input Data Card CRIGD1 Rigid Element Connection

Description: Defines a rigid element in which all six degrees of freedom of each of the dependent grid points are coupled to all six degrees of freedom of the reference grid point.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CRIGD1	EID	IG	G1	G2	G3	G4	G5	G6	abc
CRIGD1	101	15	18	43	9	26	35	41	123
+bc	G7	G8	G8	etc.					
+23	8	63							

Alternate Form:

CRIGD1	EID	IG	GID1	"THRU"	GID2				
CRIGD1	201	25	71	THRU	80				

Field	Contents
EID	Element identification number (Integer > 0)
IG	Identification number of the reference grid point (Integer > 0)
Gi, GIDi	Identification numbers of the dependent grid points (Integer > 0)

Remarks:
1. Element identification numbers must be unique with respect to all other element identification numbers.
2. Only one reference grid point is allowed per element. It must appear before any of the dependent grid points.
3. Any number of dependent grid points may be specified.
4. When the alternate form is used, no continuation card is permitted and all grid points implied by GID1 thru GID2 (GID1 < GID2) must exist.
5. Dependent degrees of freedom defined (implicitly) in a RIGD1 element may not appear on ØMIT, ØMIT1, SPC, SPC1 or SUPØRT cards nor may they be redundantly implied on ASET or ASET1 cards. They also may not appear as dependent degrees of freedom in RIGD2, RIGD3 or RIGDR elements or on MPC cards.
6. Rigid elements are not allowed in heat transfer analysis.
7. For a discussion of rigid elements, see Section 3.5.6 of the Theoretical Manual.

Input Data Card CRIGD2 Rigid Element Connection

Description: Defines a rigid element in which selected degrees of freedom of the dependent grid points are coupled to all six degrees of freedom of the reference grid point.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CRIGD2	EID	IG	G1	C1	G2	C2	G3	C3	abc
CRIGD2	102	20	9	12	45	123	53	135	123
+bc	G4	C4	etc.						
+23	27	456							

Field	Contents
EID	Element identification number (Integer > 0)
IG	Identification number of the reference grid point (Integer > 0)
Gi	Identification numbers of the dependent grid points (Integer > 0)
Ci	List of selected degrees of freedom associated with the preceding dependent grid point (any of the digits 1-6 with no imbedded blanks)

Remarks:

1. Element identification numbers must be unique with respect to all other element identification numbers.
2. Only one reference grid point is allowed per element. It must appear before the dependent grid point data.
3. Any number of dependent grid points may be specified.
4. Dependent degrees of freedom defined in a RIGD2 element may not appear on ØMIT, ØMIT1, SPC, SPC1 or SUPØRT cards nor may they be redundantly implied on ASET or ASET1 cards. They also may not appear as dependent degrees of freedom in RIGD1, RIGD3 or RIGDR elements or on MPC cards.
5. Rigid elements are not allowed in heat transfer analysis.
6. For a discussion of rigid elements, see Section 3.5.6 of the Theoretical Manual.

Input Data Card CRIGD3 General Rigid Element Connection

Description: Defines a rigid element in which selected degrees of freedom of the dependent grid points are coupled to six selected degrees of freedom at one or more (up to six) reference grid points.

Format and Example

1	2	3	4	5	6	7	8	9	10
CRIGD3	EID	IG1	IC1	IG2	IC2	IG3	IC3		abc
CRIGD3	103	11	1	12	2	13	4		ABC
+bc		IG4	IC4	IG5	IC5	IG6	IC6		def
+BC		14	35	15	6				DEF
+ef	"MSET"	DG1	DC1	DG2	DC2	DG3	DC3		ghi
+EF	MSET	21	123	22	1	23	123456		GHI
+hi		DG4	DC4	DG5	DC5	etc.			
+HI		24	456	25	2				

Field	Contents
EID	Element identification number (Integer > 0)
IGi	Identification numbers of the reference grid points (Integer > 0)
ICi	List of selected degrees of freedom associated with the preceding reference grid point (any of the digits 1-6 with no imbedded blanks)
"MSET"	BCD string that indicates the start of the data for the dependent grid points
DGi	Identification numbers of the dependent grid points (Integer > 0)
DCi	List of selected degrees of freedom associated with the preceding dependent grid point (any of the digits 1-6 with no imbedded blanks)

Remarks:

1. Element identification numbers must be unique with respect to all other element identification numbers.
2. The total number of degrees of freedom specified for the reference grid points (IC1 through IC6) must be six. Further, they should together be capable of representing any general rigid body motion of the element.
3. The first continuation card is not required if less than four reference grid points are specified.
4. The BCD word MSET is required in order to indicate the start of the dependent grid point data.
5. Any number of dependent grid points may be specified.

(Continued)

CRIGD3 (Cont.)

6. Dependent degrees of freedom defined in a RIGD3 element may not appear on ØMIT, ØMIT1, SPC, SPC1 or SUPØRT cards nor may they be redundantly implied on ASET or ASET1 cards. They also may not appear as dependent degrees of freedom in RIGD1, RIGD2 or RIGDR elements or on MPC cards.

7. Rigid elements are not allowed in heat transfer analysis.

8. For a discussion of rigid elements, see Section 3.5.6 of the Theoretical Manual.

NASTRAN DATA DECK

Input Data Card CRIGDR Rigid Rod Element Connection

Description: Defines a pin-ended rod element that is rigid in extension-compression.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CRIGDR	EID	G	G1	C1	EID	G	G1	C1	
CRIGDR	104	5	9	3	302	12	4	2	

Field	Contents
EID	Element identification number (Integer > 0)
G	Identification number of the reference grid point (Integer > 0)
G1	Identification number of the dependent grid point (Integer > 0; G1 ≠ G)
C1	Dependent translational degree of freedom of grid point G1 (1 ≤ Integer ≤ 3)

Remarks:

1. Element identification numbers must be unique with respect to all other element identification numbers.
2. Only one reference grid point and only one dependent grid point are allowed per element. The two points may not be coincident.
3. The direction represented by the dependent translational degree of freedom of the dependent grid point may not be perpendicular or nearly perpendicular to the element.
4. One or two RIGDR elements may be defined on a single card.
5. Dependent degrees of freedom defined in a RIGDR element may not appear on ØMIT, ØMIT1, SPC, SPC1 or SUPØRT cards nor may they be redundantly implied on ASET or ASET1 cards. They also may not appear as dependent degrees of freedom in RIGD1, RIGD2 or RIGD3 elements or on MPC cards.
6. Rigid elements are not allowed in heat transfer analysis.
7. For a discussion of rigid elements, see Section 3.5.6 of the Theoretical Manual.

Input Data Card CRØD Rod Element Connection

Description: Defines a tension-compression-torsion element (RØD) of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CRØD	EID	PID	G1	G2	EID	PID	G1	G2	
CRØD	12	13	21	23	3	12	24	5	

Field	Contents
EID	Element identification number (Integer > 0)
PID	Identification number of a PRØD property card (Default is EID) (Integer > 0)
G1, G2	Grid point identification numbers of connection points (Integer > 0; G1 ≠ G2)

Remarks:

1. Element identification numbers must be unique with respect to all other element identification numbers.
2. See CØNRØD for alternative method of rod definition.
3. One or two RØD elements may be defined on a single card.

NASTRAN DATA DECK

Input Data Card CSHEAR   Shear Panel Element Connection

Description: Defines a shear panel element (SHEAR) of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CSHEAR	EID	PID	G1	G2	G3	G4			
CSHEAR	3	6	1	5	3	7			

Field	Contents
EID	Element identification number (Integer > 0)
PID	Identification number of a PSHEAR property card (Default is EID) (Integer > 0)
G1, G2, G3, G4	Grid point identification numbers of connection points (Integer > 0; G1 ≠ G2 ≠ G3 ≠ G4)

Remarks:
1. Element identification numbers must be unique with respect to all other element identification numbers.
2. Grid points G1 thru G4 must be ordered consecutively around the perimeter of the element.
3. All interior angles must be less than 180°.

Input Data Card CSLØTi Slot Element Connections

Description: Defines an element connecting i = 3 or i = 4 points which solves the wave equation in two dimensions. Used in the acoustic cavity analysis for the definition of evenly spaced radial slots.

Formats and Examples:

1	2	3	4	5	6	7	8	9	10
CSLØT3	EID	IDS1	IDS2	IDS3		RHØ	B	M	
CSLØT3	100	1	3	2		3.E-3		6	
CSLØT4	EID	IDS1	IDS2	IDS3	IDS4	RHØ	B	M	
CSLØT4	101	1	3	2	4		6.2+4	3	

Field	Contents
EID	Element identification number (Integer > 0)
IDSj	Identification number of connected GRIDS points, j = 1,2,...J (Integer > 0)
RHØ	Fluid density in mass units (Real > 0.0 or "blank")
B	Fluid bulk modulus (Real ≥ 0.0 or blank)
M	Number of slots in circumferential direction (Integer ≥ 0, or "blank")

Remarks:
1. This card is allowed only if an AXSLØT card is also present.
2. The element identification number (IDF) must be unique with respect to all other fluid or structural elements.
3. If RHØ, B, or M are blank, the corresponding values on the AXSLØT data card are used, in which case the default value must not be blank (undefined).
4. Plot elements connecting two points at a time are generated for these elements. The CSLØT3 element generates 3 plot elements. The CSLØT4 element generates four plot elements, connecting points 1-2, 2-3, 3-4, and 4-1.
5. If B = 0.0, the slot is considered to be an incompressible fluid.
6. If M = 0 no matrices for CSLØTi elements are generated.

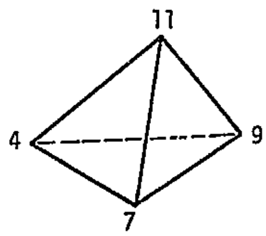
Input Data Card CTETRA Tetrahedron Element Connection

Description: Defines a tetrahedron element (3 dimensional solid with 4 vertices and 4 triangular faces, TETRA) of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CTETRA	EID	MID	G1	G2	G3	G4			
CTETRA	15	2	4	7	9	11			

Field	Contents
EID	Element identification number (Integer > 0)
MID	Material identification number (Integer > 0)
G1,G2,G3,G4	Grid point identification numbers of connection points (Integers > 0, G1 ≠ G2 ≠ G3 ≠ G4)



Remarks:
1. Element identification numbers must be unique with respect to all other element identification numbers.
2. There is no nonstructural mass.
3. For structural problems, material must be defined by MAT1 card.
4. Output stresses are given in basic coordinate system.
5. For heat transfer problems, material may be defined with either a MAT4 or MAT5 card.

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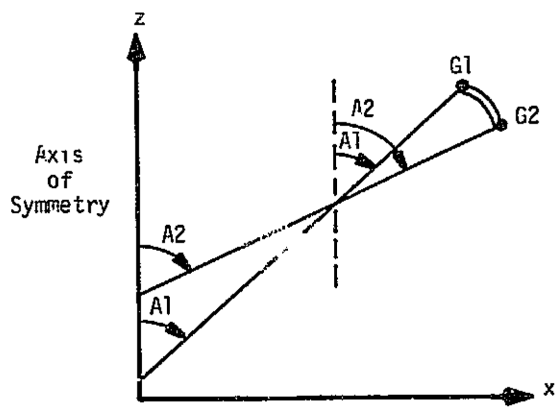
Input Data Card CTØRDRG Toroidal Ring Element Connection

Description: Defines an axisymmetric toroidal cross-section ring element (TØRDRG) of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CTØRDRG	EID	PID	G1	G2	A1	A2			
CTØRDRG	25	2	47	48	30.0	60.0			

Field	Contents
EID	Element identification number (Integer > 0)
PID	Property identification number (Default is EID) (Integer > 0)
G1, G2	Grid Point identification numbers of connection points (Integer > 0; G1 ≠ G2)
A1	Angle of curvature at grid point 1 in degrees (Real; 0° ≤ A1 ≤ 180°; A2 ≥ A1)
A2	Angle of curvature at grid point 2 in degrees (Real; 0° ≤ A2 ≤ 180°; A2 ≥ A1)



Remarks:
1. Element identification numbers must be unique with respect to all other element identification numbers.
2. Grid points G1 and G2 must lie in the x-z plane of the basic coordinate system and to the right of the axis of symmetry (the z-axis).
3. If A1 = 0, the element is assumed to be a shell cap.
4. Only elements of zero or positive Gaussian curvature may be used.

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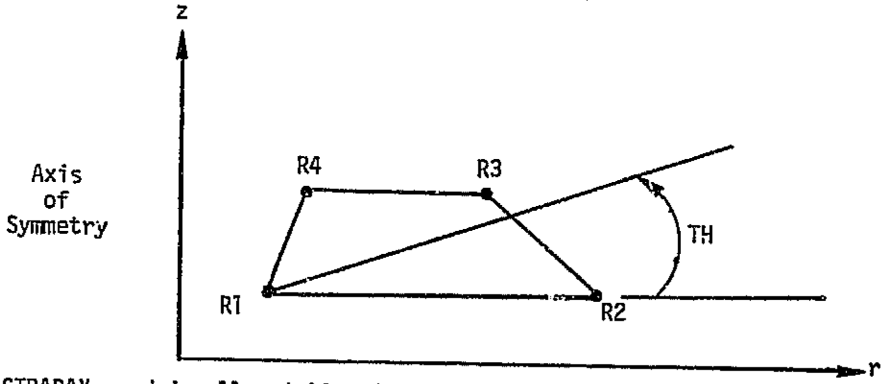
Input Data Card CTRAPAX Trapezoidal Ring Element Connection

Description: Defines an axisymmetric trapezoidal cross-section ring element with non-axisymmetric deformation of the structural model with reference to property card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CTRAPAX	EID	PID	R1	R2	R3	R4	TH		
CTRAPAX	15	5	10	11	12	13	30.0		

Field	Contents
EID	Element identification number (Integer > 0)
PID	Identification number of a PTRAPAX card (Integer > 0)
R1,R2,R3,R4	Identification numbers of RINGAX cards (Integer > 0; R1 ≠ R2 ≠ R3 ≠ R4)
TH	Material property orientation angle in degrees (Real) - The sketch below gives the sign convention for TH.



Remarks:
1. CTRAPAX card is allowed if and only if an AXIC card is also present.
2. Element identification numbers must be unique with respect to all other element identification numbers.
3. RINGAX identification numbers R1, R2, R3 and R4 must be ordered counterclockwise around the perimeter.
4. For a discussion of the axisymmetric ring problem, see Section 5.11 of the Theoretical Manual.
5. The lines connecting R1 to R2 and R4 to R3 must be parallel to the r axis.
6. This element cannot be modeled with a grid point on the axis of symmetry.

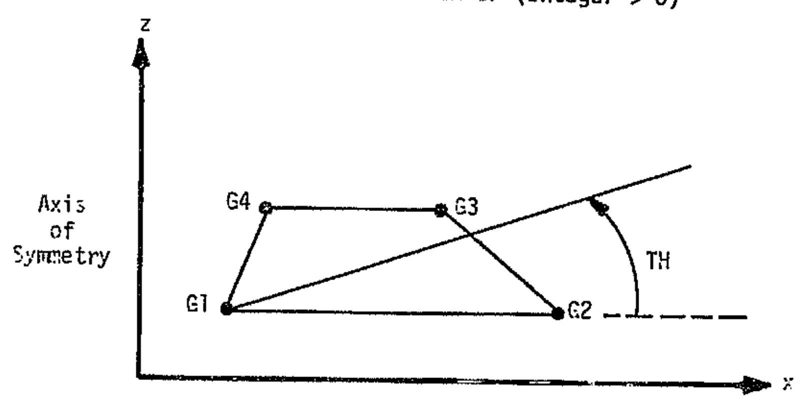
Input Data Card CTRAPRG   Trapezoidal Ring Element Connection

Description: Defines an axisymmetric trapezoidal cross-section ring element (TRAPRG) of the structural model without reference to a property card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CTRAPRG	EID	G1	G2	G3	G4	TH	MID		
CTRAPRG	72	13	14	15	16	29.2	13		

Field	Contents
EID	Element identification number (Integer > 0)
G1,G2,G3,G4	Grid point identification number of connection points (Integers > 0; G1 ≠ G2 ≠ G3 ≠ G4)
TH	Material property orientation angle in degrees (Real) - The sketch below gives the sign convention for TH.
MID	Material property identification number (Integer > 0)



Remarks:
1. Element identification numbers must be unique with respect to all other element identification numbers.
2. The four grid points must lie in the x-z plane of both the basic and any local coordinate systems and to the right of the axis of symmetry (the z-axis).
3. Grid points G1, G2, G3 and G4 must be ordered counterclockwise around the perimeter of the element as in the above sketch.
4. The line connecting grid points G1 and G2 and the line connecting grid points G3 and G4 must both be parallel to the x-axis.
5. All interior angles must be less than 180°.
6. For structural problems, the material property identification number must reference only a MAT1 or MAT3 card.
7. For heat transfer problems, the material property identification number must reference only a MAT4 or MAT5 card.

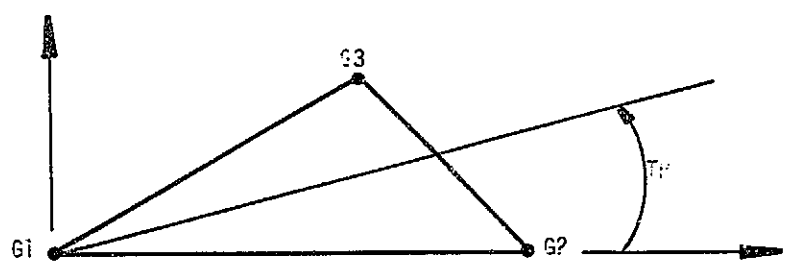
Input Data Card CTRBSC Triangular Element Connection

Description: Defines a basic triangular bending element (TRBSC) of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CTRBSC	EID	PID	G1	G2	G3	TH			
CTRBSC	16	2	12	1	3	16.2			

Field	Contents
EID	Element identification number (Integer > 0)
PID	Identification number of a PTRBSC property card (Default is EID) (Integer > 0)
G1,G2,G3	Grid point identification numbers of connection points (Integer > 0; G1 ≠ G2 ≠ G3)
TH	Material property orientation angle in degrees (Real) - The sketch below gives the sign convention for TH.



Remarks: 1. Element identification numbers must be unique with respect to all other element identification numbers.

2. Interior angles must be less than 180°.

3. No structural mass is generated by this element.

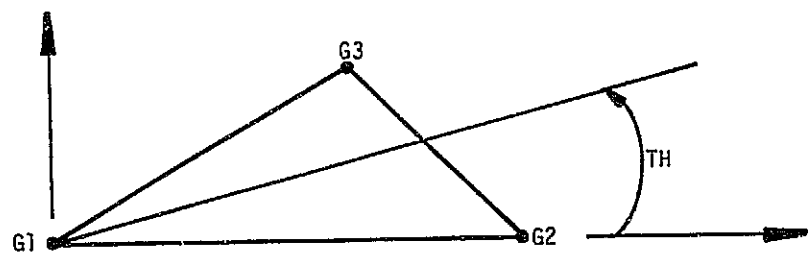
Input Data Card CTRIA1 Triangular Element Connection

Description: Defines a triangular membrane and bending element (TRIA1) of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CTRIA1	EID	PID	G1	G2	G3	TH			
CTRIA1	16	2	12	1	3	16.2			

Field	Contents
EID	Element identification number (Integer > 0)
PID	Identification number of a PTRIA1 property card (Default is EID) (Integer > 0)
G1,G2,G3	Grid point identification numbers of connection points (Integer > 0; G1 ≠ G2 ≠ G3)
TH	Material property orientation angle in degrees (Real) - The sketch below gives the sign convention for TH.



Remarks: 1. Element identification numbers must be unique with respect to all other element identification numbers.

2. Interior angles must be less than 180°.

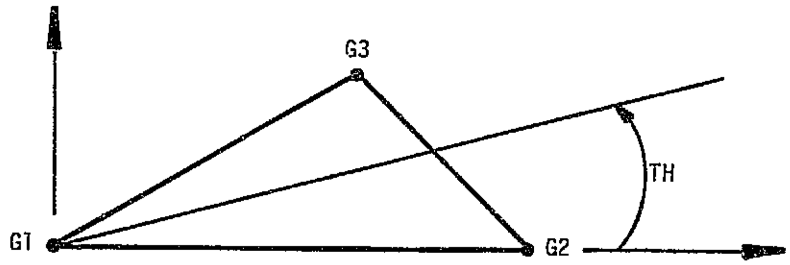
Input Data Card CTRIA2 Triangular Element Connection

Description: Defines a triangular membrane and bending element (TRIA2) of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CTRIA2	EID	PID	G1	G2	G3	TH			
CTRIA2	16	2	12	1	3	16.2			

Field	Contents
EID	Element identification number (Integer > 0)
PID	Identification number of a PTRIA2 property card (Default is EID) (Integer > 0)
G1,G2,G3	Grid point identification numbers of connection points (Integer > 0; G1 ≠ G2 ≠ G3)
TH	Material property orientation angle in degrees (Real) - The sketch below gives the sign convention for TH.



Remarks: 1. Element identification numbers must be unique with respect to all other element identification numbers.

2. Interior angles must be less than 180°.

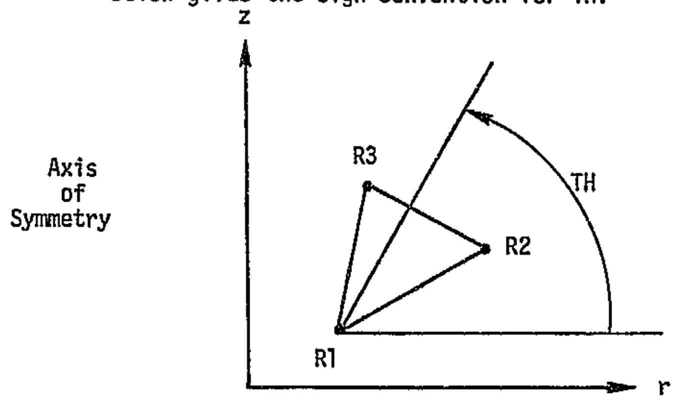
Input Data Card CTRIAAX Triangular Ring Element Connection

Description: Defines an axisymmetric triangular cross-section ring element with non-axisymmetric deformation of the structural model with reference to property card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CTRIAAX	EID	PID	R1	R2	R3	TH			
CTRIAAX	20	15	42	43	52	60.0			

Field	Contents
EID	Element identification number (Integer > 0)
PID	Identification number of a PTRIAAX card (Integer > 0)
R1,R2,R3	Identification numbers of RINGAX cards (Integer > 0; R1 ≠ R2 ≠ R3)
TH	Material property orientation angle in degrees (Real) - The sketch below gives the sign convention for TH.



Remarks:
1. CTRIAAX card is allowed if and only if an AXIC card is also present.
2. Element identification numbers must be unique with respect to all other element identification numbers.
3. RINGAX identification numbers R1,R2 and R3 must be ordered counterclockwise around the perimeter.
4. For a discussion of the axisymmetric ring problem, see Section 5.11 of the Theoretical Manual.

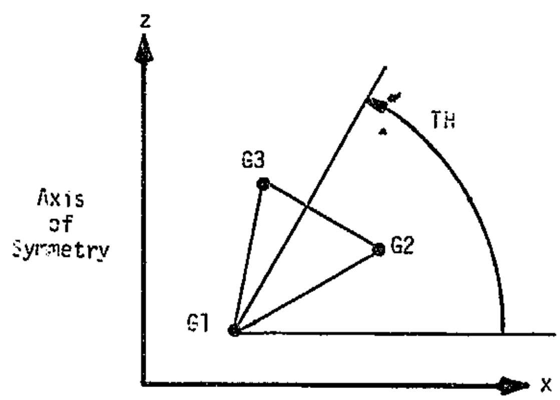
Input Data Card CTRIARG Triangular Ring Element Connection

Description: Defines an axisymmetric triangular cross section ring element (TRIARG) of the structural model without reference to a property card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CTRIARG	EID	G1	G2	G3	TH	MID			
CTRIARG	16	12	13	14	29.2	17			

Field	Contents
EID	Element identification number (Integer > 0)
G1, G2, G3	Grid point identification numbers of connection points (Integers > 0; G1 ≠ G2 ≠ G3)
TH	Material property orientation angle in degrees (Real) - The sketch below gives the sign convention for the TH.
MID	Material identification number (Integer > 0)



Remarks:

1. Element identification numbers must be unique with respect to all other element identification numbers.
2. The grid points must lie in the x-z plane of both the basic and any local coordinate systems and to the right of the axis of symmetry (the z-axis).
3. Grid points G1, G2 and G3 must be ordered counterclockwise around the perimeter of the element as shown in the above sketch.
4. For structural problems, the material property identification number must reference only a MAT1 or MAT3 card.
5. For heat transfer problems, the material property identification number must reference only a MAT4 or MAT5 card.

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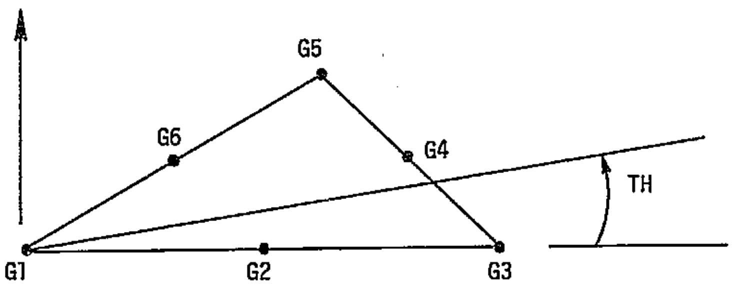
Input Data Card CTRIM6 Linear Strain Triangular Element Connection

Description: Defines a linear strain triangular membrane element (TRIM6) of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CTRIM6	EID	PID	G1	G2	G3	G4	G5	G6	+abc
CTRIM6	220	666	100	110	120	210	220	320	AC3
+abc	TH								
+C3	90.0								

Field	Contents
EID	Element identification number (Integer > 0).
PID	Identification number of PTRIM6 property card (Default is EID) (Integer >0).
G1, G2, G3, G4, G5, G6	Grid point identification numbers of connection points (Integers > 0); G1 ≠ G2 ≠ G3 ≠ G4 ≠ G5 ≠ G6).
TH	Material property orientation angle in degrees (Real). The sketch below gives the sign convention for TH.



Remarks:

1. Element identification numbers must be unique with respect to all other element identification numbers.
2. Interior angles must be less than 180°.
3. The gridpoints must be ordered consecutively around the perimeter in a counter clockwise direction and starting at a vertex.
4. Material properties (if MAT2 card is used) and stresses are given in the material coordinate system.
5. The continuation card must be present.
6. Grid points G2, G4, and G6 are assumed to lie at the midpoints of the sides. The locations of these points (defined by GRID cards) are used only for the global coordinate system definition, the Grid Point Weight Generator, centrifugal forces, and deformed structure plotting.

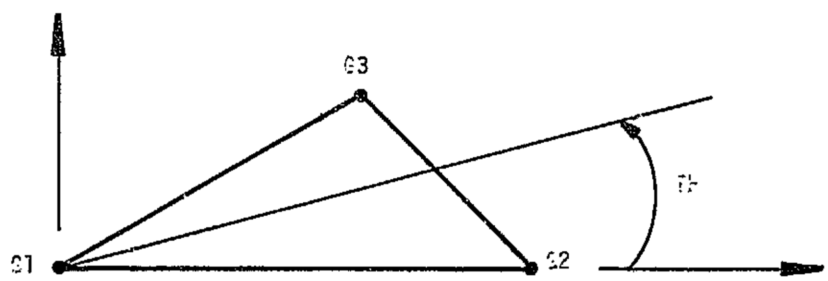
Input Data Card CTRMEM Triangular Element Connection

Description: Defines a triangular membrane element (TRMEM) of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CTRMEM	EID	PID	G1	G2	G3	TH			
CTRMEM	16	2	12	1	3	16.3			

Field	Contents
EID	Element identification number (Integer > 0)
PID	Identification number of a PTRMEM property card (Default is EID) (Integer > 0)
G1,G2,G3	Grid point identification numbers of connection points (Integer > 0; G1 ≠ G2 ≠ G3)
TH	Material property orientation angle in degrees (Real) - The sketch below gives the sign convention for TH.



Remarks: 1. Element identification numbers must be unique with respect to all other element identification numbers.

2. Interior angles must be less than 180°.

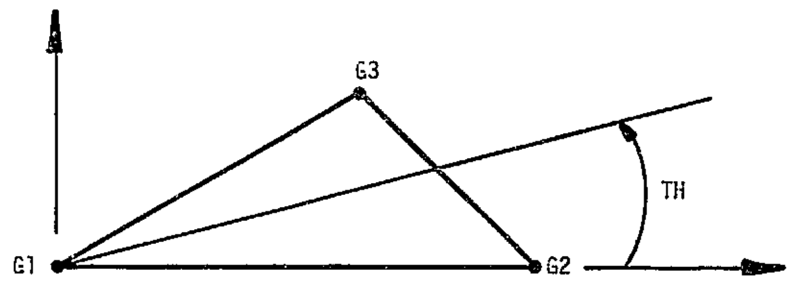
Input Data Card CTRPLT Triangular Element Connection

Description: Defines a triangular bending element (TRPLT) of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CTRPLT	EID	PID	G1	G2	G3	TH			
CTRPLT	16	2	12	1	3	16.2			

Field	Contents
EID	Element identification number (Integer > 0)
PID	Identification number of a PTRPLT property card (Default is EID) (Integer > 0)
G1,G2,G3	Grid point identification numbers of connection points (Integer > 0; G1 ≠ G2 ≠ G3)
TH	Material property orientation angle in degrees (Real) - The sketch below gives the sign convention for TH.



Remarks: 1. Element identification numbers must be unique with respect to all other element identification numbers.

2. Interior angles must be less than 180°.

3. No structural mass is generated by this element.

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Input Data Card CTRPLT1 Triangular Element Connection

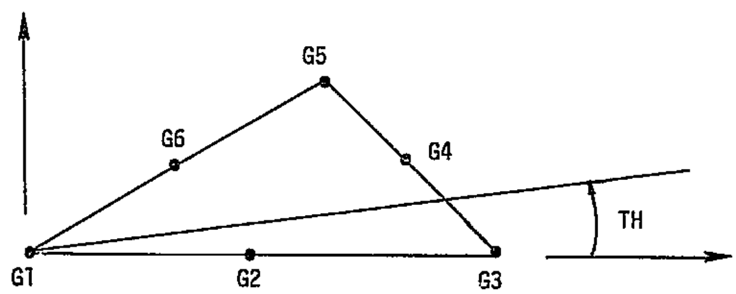
Description: Defines a higher order triangular bending element (TRPLT1) of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CTRPLT1	EID	PID	G1	G2	G3	G4	G5	G6	abc
CTRPLT1	160	20	120	10	30	40	70	110	ABC

+bc	TH								
+BC	16.2								

Field	Contents
EID	Element identification number (Integer > 0)
PID	Identification number of PTRPLT1 property card (Default is EID) (Integer > 0)
G1, G2, G3, G4, G5, G6	Grid point identification numbers of connection points (Integer > 0; G1 ≠ G2 ≠ G3 ≠ G4 ≠ G5 ≠ G6)
TH	Material property orientation angle in degrees (Real)- The sketch below gives the sign convention for TH.



Remarks: 1. Element identification numbers must be unique with respect to all other element identification numbers.

2. Interior angles must be less than 180°.

3. The grid points must be ordered consecutively around the perimeter in counterclockwise direction and starting at a vertex.

4. The continuation card is required.

Input Data Card CTRSHL Triangular Shell Element Connection

Description: Defines a triangular thin shallow shell element (TRSHL) of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CTRSHL	EID	PID	G1	G2	G3	G4	G5	G6	abc
CTRSHL	160	20	120	10	30	40	10	30	ABC

+bc	TH								
+BC	16.2								

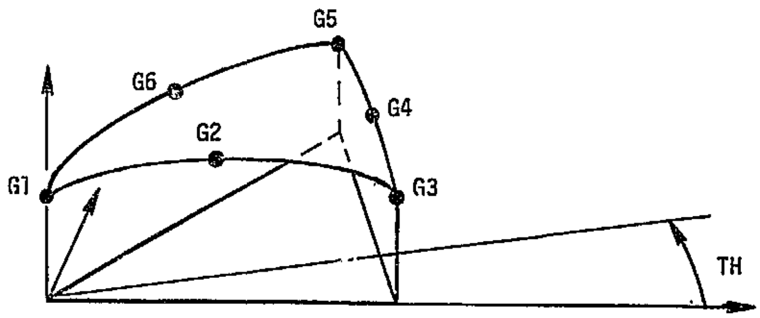
Field

EID Element identification number (Integer > 0)

PID Identification number of PTRSHL property card (Default is EID) (Integer > 0)

G1, G2, G3, G4, G5, G6 Grid point identification numbers of connection points (Integers > 0; G1 ≠ G2 ≠ G3 ≠ G4 ≠ G5 ≠ G6)

TH Material property orientation angle in degrees (Real) - The sketch below gives the sign convention for TH.



Remarks: 1. Element identification numbers must be unique with respect to all other element identification numbers.

2. Interior angles must be less than 180^0.

3. The grid points must be listed consecutively around the perimeter in counter-clockwise direction starting at a vertex.

4. The continuation card must be present.

Input Data Card CTUBE Tube Element Connection

Description: Defines a tension-compression-torsion element (TUBE) of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CTUBE	EID	PID	G1	G2	EID	PID	G1	G2	
CTUBE	12	13	21	23	3	12	24	5	

Field	Contents
EID	Element identification number (Integer > 0)
PID	Identification number of a PTUBE property card (Default is EID) (Integer > 0)
G1, G2	Grid point identification numbers of connection points (Integer > 0; G1 ≠ G2)

Remarks: 1. Element identification numbers must be unique with respect to all other element identification numbers.

2. One or two TUBE elements may be defined on a single card.

Input Data Card CTWIST Twist Panel Element Connection

Description: Defines a twist panel element (TWIST) of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CTWIST	EID	PID	G1	G2	G3	G4			
CTWIST	2	6	1	5	3	7			

Field	Contents
EID	Element identification number (Integer > 0)
PID	Identification number of a PTWIST property card (Default is EID) (Integer > 0)
G1,G2,G3,G4	Grid point identification numbers of connection points (Integer > 0; G1 ≠ G2 ≠ G3 ≠ G4)

Remarks:

1. Element identification numbers must be unique with respect to all other element identification numbers.
2. Grid points G1 thru G4 must be ordered consecutively around the perimeter of the element.
3. All interior angles must be less than 180°.

Input Data Card CVISC Viscous Damper Connection

Description: Defines a viscous damper element (VISC) of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CVISC	EID	PID	G1	G2	EID	PID	G1	G2	
CVISC	21	6327	29	31	22	6527	35	33	

Field	Contents
EID	Element identification number (Integer > 0)
PID	Identification number of PVISC property card (Default is EID) (Integer > 0)
G1, G2	Grid point identification numbers of connection points (Integer > 0; G1 ≠ G2)

Remarks:
1. Element identification numbers must be unique with respect to all other element identification numbers.
2. One or two VISC elements may be defined on a single card.
3. Used only for direct formulation of dynamic analyses.

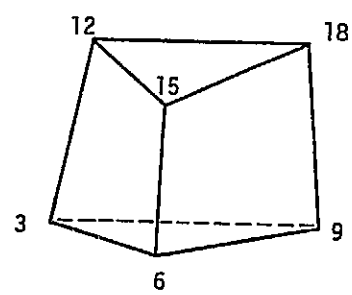
Input Data Card <u>CWEDGE</u> Wedge Element Connection

Description: Defines a wedge element (3 dimensional solid, with three quadrilateral faces and two opposing triangular faces, WEDGE) of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CWEDGE	EID	MID	G1	G2	G3	G4	G5	G6	
CWEDGE	15	2	3	6	9	12	15	18	

Field	Contents
EID	Element identification number (Integer > 0)
MID	Material identification number (Integer > 0)
G1,...,G6	Grid point identification numbers of connection points (Integers > 0, G1 ≠ G2 ≠ ... ≠ G6)



Remarks:
1. Element identification numbers must be unique with respect to all other element identification numbers.
2. The order of the grid points is: G1, G2, G3 on one triangular face, G4, G5, G6 at the other triangular face. G1, G4 on a common edge, G2, G5 on a common edge.
3. The quadrilateral faces must be nearly planar.
4. There is no nonstructural mass.
5. For structural problems, material must be defined by MAT1 card.
6. Output stresses are given in the basic coordinate system.
7. For heat transfer problems, material may be defined with either a MAT4 or MAT5 card.

NASTRAN DATA DECK

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Input Data Card CYJØIN

Description: Defines the boundary points of a segment for cyclic symmetry structural molds.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CYJØIN	SIDE	C	G1	G2	G3	G4	G5	G6	abc
CYJØIN	1		7	9	16	25	33	64	ABC
+bc	G7	G8	G9	-etc.-					
+BC	72								

Alternate Form

CYJØIN	SIDE	C	GID1	"THRU"	GID2				
CYJØIN	2	S	6	THRU	32				

Field	Contents
SIDE	Side identification (Integer 1 or 2)
C	Coordinate System (BCD value R,C or S or blank)
Gi,GIDi	Grid or scalar point identification numbers (Integer > 0)

Remarks:

1. CYJØIN bulk data cards are only used for cyclic symmetry problems. A parameter (CTYPE) must specify rotational or dihedral symmetry.

2. For rotational symmetry problems there must be one logical card for side 1 and one for side 2. The two lists specify grid points to be connected, hence both lists must have the same length.

3. For dihedral symmetry problems, side 1 refers to the boundary between segments and side 2 refers to the middle of a segment. A coordinate system must be referenced in field 3, where R = rectangular C = cylindrical and S = spherical.

4. All components of displacement at boundary points are connected to adjacent segments, except those constrained by SPC, MPC or ØMIT.

Input Data Card DAREA Dynamic Load Scale Factor

Description: This card is used in conjunction with the RLØAD1, RLØAD2, TLØAD1, and TLØAD2 data cards and defines the point where the dynamic load is to be applied with the scale (area) factor A.

Format and Example:

1	2	3	4	5	6	7	8	9	10
DAREA	SID	P	C	A	P	C	A	X	
DAREA	3	6	2	8.2	15	1	10.1		

Field	Contents
SID	Identification number of DAREA set (Integer > 0)
P	Grid or scalar point identification number (Integer > 0)
C	Component number (1-6 for grid point; blank or 0 for scalar point)
A	Scale (area) factor A for the designated coordinate (Real)

Remarks: One or two scale factors may be defined on a single card.

Input Data Card DAREAS   Dynamic Load Scale Factor - Substructure Analysis

Description: This card is used in conjunction with the RLØAD1, RLØAD2, TLØAD1, and TLØAD2 data cards and defines the point where the dynamic load is to be applied with the scale (area) factor A.

Format and Example:

1	2	3	4	5	6	7	8	9	10
DAREAS	SID	NAME	P	C	A	P	C	A	
DAREAS	3	SKIN	6	2	8.2	15	1	10.1	

Field	Contents
SID	Identification number of DAREA set (Integer > 0)
NAME	Basic substructure name
P	Grid or scalar point identification number (Integer > 0)
C	Component number (1-6 for grid point; blank or 0 for scalar point)
A	Scale (area) factor A for the designated coordinate (Real)

Remarks:
1. One or two scale factors may be defined on a single card
2. Used in substructure SØLVE operation
3. Points referenced must exist in the SØLVEd structure.

Input Data Card DEFØRM Element Deformation

Description: Defines enforced axial deformation for one-dimensional elements for use in statics problems.

Format and Example:

1	2	3	4	5	6	7	8	9	10
DEFØRM	SID	EID	D	EID	D	EID	D		
DEFØRM	1	535	.05	536	-.10				

Field	Contents
SID	Deformation set identification number (Integer > 0)
EID	Element number (Integer > 0)
D	Deformation (+ = elongation) (Real)

Remarks:

1. The referenced element must be one-dimensional (i.e., a RØD (including CØNRØD), TUBE or BAR).
2. Deformation sets must be selected in the Case Control Deck (DEFØRM=SID) to be used by NASTRAN.
3. From one to three enforced element deformations may be defined on a single card.

Input Data Card DELAY Dynamic Load Time Delay

Description: This card is used in conjunction with the RLØAD1, RLØAD2, TLØAD1 and TLØAD2 data cards and defines the time delay term τ in the equations of the loading function.

Format and Example:

1	2	3	4	5	6	7	8	9	10
DELAY	SID	P	C	T	P	C	T		
DELAY	5	21	6	4.25	7	6	8.1		

Field	Contents
SID	Identification number of DELAY set (Integer > 0)
P	Grid or scalar point identification number (Integer > 0)
C	Component number (1-6 for grid point, blank or 0 for scalar point)
T	Time delay τ for designated coordinate (Real)

Remarks: One or two dynamic load time delays may be defined on a single card.

Input Data Card DELAYS Dynamic Load Time Delay - Substructure Analysis

Description: This card is used in conjunction with the RLØAD1, RLØAD2, TLØAD1 and TLØAD2 data cards and defines the time delay term τ in the equations of the loading function.

Format and Example:

1	2	3	4	5	6	7	8	9	10
DELAYS	SID	NAME	P	C	T	P	C	T	
DELAYS	5	SKIN	21	6	4.25	7	6	8.1	

Field	Contents
SID	Identification number of DELAY set (Integer > 0)
NAME	Basic substructure name
P	Grid or scalar point identification number (Integer > 0)
C	Component number (1-6 for grid point, blank or 0 for scalar point)
T	Time delay τ for designated coordinate (Real)

Remarks:
1. One or two dynamic load time delays may be defined on a single card.
2. Used in substructure SOLVE operation.
3. Points referenced must exist in the SØLVEd structure.

Input Data Card DLØAD Dynamic Load Combination (Superposition)

Description: Defines a dynamic loading condition for frequency response or transient response problems as a linear combination of load sets defined via RLØAD1 or RLØAD2 cards (for frequency response) or TLØAD1 or TLØAD2 cards (for transient response).

Format and Example:

1	2	3	4	5	6	7	8	9	10
DLØAD	SID	S	S1	L1	S2	L2	S3	L3	+abc
DLØAD	17	1.0	2.0	6	-2.0	7	2.0	8	+A

+abc	S4	L4		-etc.-					
+A	-2.0	9							

-etc.-

Field	Contents
SID	Load set identification number (Integer > 0)
S	Scale Factor (Real)
Si	Scale Factors (Real)
Li	Load set identification numbers defined via card types enumerated above (Integer > 0)

Remarks: 1. The load vector being defined by this card is given by

$$\{P\} = S \sum_i Si\{P_{Li}\}.$$

2. The Li must be unique.
3. SID must be unique from all Li.
4. Nonlinear transient loads may not be included; they are selected separately in the Case Control Deck.
5. Linear load sets must be selected in the Case Control Deck (DLØAD=SID) to be used by NASTRAN.
6. A DLØAD card may not reference a set identification number defined by another DLØAD card.
7. TLØAD1 and TLØAD2 loads may be combined only thru the use of the DLØAD card.
8. RLØAD1 and RLØAD2 loads may be combined only thru the use of the DLØAD card.
9. SID must be unique for all TLØAD1, TLØAD2, RLØAD1, and RLØAD2 cards.

Input Data Card DMI   Direct Matrix Input

Description: Used to define matrix data blocks directly. Generates a matrix of the form

$$[A] = \begin{bmatrix} A_{11} & A_{12} \cdots\cdots & A_{1n} \\ A_{21} & A_{22} \cdots\cdots & A_{2n} \\ \vdots & \vdots & \vdots \\ A_{m1} & \cdots\cdots\cdots & A_{mn} \end{bmatrix}$$

where the elements A_{ij} may be real or complex single-precision or double precision numbers.

Formats and Example: (The first logical card is a header card.)

1	2	3	4	5	6	7	8	9	10
DMI	NAME	"0"	FØRM	TIN	TØUT		M	N	
DMI	QQQ	0	2	3	3		4	2	
DMI	NAME	J	I1	A(I1,J)	A(I1+1,J)		etc.	I2	+abc
DMI	QQQ	1	1	1.0	2.0	3.0	4.0	3	+1
+abc	A(I2,J)		etc.						
+1	5.0	6.0							
DMI	QQQ	2	2	6.0	7.0	4	8.0	9.0	

(etc. for each nonnull column)

Field	Contents
NAME	Any NASTRAN BCD value (1-8 alphnumeric characters, the first of which must be alphabetic) which will be used in the DMAP sequence to reference the data block
FØRM	1 Square matrix (not symmetric) 2 General rectangular matrix 6 Symmetric matrix
TIN	Type of matrix being input as follows: 1 Real, single-precision (One field is used per element) 2 Real, double-precision (One field is used per element) 3 Complex, single-precision (Two fields are used per element) 4 Complex, double-precision (Two fields are used per element)
TØUT	Type of matrix which will be created 1 Real, single-precision 3 Complex, single-precision 2 Real, double-precision 4 Complex, double-precision
M	Number of rows in A (Integer > 0)
N	Number of columns in A (Integer > 0)
J	Column number of A (Integer > 0)
I1,I2,etc.	Row number of A (Integer > 0)
A(Ix,J)	Element of A (See TIN) (Real)

(Continued)

DMI (Cont.)

Remarks: 1. The user must write a DMAP (or make alterations to a rigid format) in order to use the DMI feature since he is defining a data block. All of the rules governing the use of data blocks in DMAP sequences apply. In the example shown above, the data block QQQ is defined to be the complex, single-precision rectangular 4x2 matrix

$$[QQQ] = \begin{bmatrix} (1.0,\ 2.0) & (0.0,\ 0.0) \\ (3.0,\ 4.0) & (6.0,\ 7.0) \\ (5.0,\ 6.0) & (0.0,\ 0.0) \\ (0.0,\ 0.0) & (8.0,\ 9.0) \end{bmatrix}$$

The DMAP data block NAME (QQQ in the example) will appear in the initial FIAT and the data block will initially appear on the Data Pool File (PØØL).

2. A limit to the number of DMI's which may be defined is set by the size of the Data Pool Dictionary. The total number of DMI's may not exceed this size.

3. There are a number of reserved words which may not be used for DMI names. Among these are PØØL, NPTP, ØPTP, UMF, NUMF, PLT1, PLT2, INPT, INP1 through INP9, GEØM1, GEØM2, GEØM3, GEØM4, GEØM5, EDT, MPT, EPT, DIT, DYNAMICS, IFPFILE, AXIC, FØRCE, MATPØØL, PCDB, XYCDB, CASECC, any DTI names, and SCRATCH1 through SCRATCH9.

4. Field 3 of the header card must contain an integer 0.

5. For symmetric matrices, the entire matrix must be input.

6. Only nonzero terms need be entered.

7. A blank field on this card is not equivalent to a zero. If zero input is desired, the appropriate type zero must be punched (i.e., 0.0 or 0.0D0).

8. Complex input must have both the real and imaginary parts punched if either part is nonzero.

9. If A (IX,J) is followed by THRU in the next field and an integer row number IY after the THRU, then A (IX,J) will be repeated in each row through IY. The THRU must follow an element value. In the example below, 3.14 will be in rows 3 through 6 of column 1 and 2.0 in row 9.

DMI	QQQ	0	2	1	1		9	1	
DMI	QQQ	1	3	3.14	THRU	6	9	2.0	

Input Data Card DMIAX Direct Axisymmetric Matrix Input

Description: Defines axisymmetric (fluid or structure) related direct input matrix terms.

Format and Example:

1	2	3	4	5	6	7	8	9	10
DMIAX	NAME	"0"	IFØ	TIN	TØUT				
DMIAX	B2PP	0	1	3	4				

1	2	3	4	5	6	7	8	9	10
DMIAX	NAME	GJ	CJ	NJ					+abc
DMIAX	B2PP	32							+BG27

1	2	3	4	5	6	7	8	9	10
+abc	GI	CI	NI	X_{ij}	Y_{ij}				+def
+BG27	1027	3		4.35+6	2.27+3				

-etc. for each column and row containing nonzero terms-

Field	Contents
NAME	BCD name of matrix (one to eight alphanumeric characters the first of which is alphabetic)
IFØ	1 Square matrix; 2 General rectangular matrix; 6 Symmetric matrix } Identification of Matrix Form
TIN	Type of matrix being input as follows: 1 Real, single-precision (One field is used per element) 3 Complex, single-precision (Two fields are used per element)
TØUT	Type of matrix which will be created 1 Real, single-precision 3 Complex, single-precision 2 Real, double precision 4 Complex, double-precision
GJ, GI	Grid, scalar, RINGFL fluid point, PRESPT pressure point, FREEPT free surface displacement, or extra point identification number (Integer > 0)
CJ, CI	Component number for GJ or GI grid point (0 ≤ Integer ≤ 6; Blank or zero if GJ or GI is a scalar, fluid, or extra point)
NJ, NI	Harmonic number of RINGFL point. Must be blank if a point type other than RINGFL is used. Negative number implies the "sine" series, positive implies the "cosine" series. (Integer)
X_{ij}, Y_{ij}	Real and Imaginary parts of matrix element; row (GI, CI, NI) column (GJ,CJ,NJ)

(Continued)

DMIAX (Cont.)

Remarks: 1. This card is allowed only if an AXIF card is also present.

2. Matrices defined on this card may be used in dynamics by selection in the Case Control Deck by K2PP=NAME, B2PP=NAME, or M2PP=NAME for $[K^2_{pp}]$, $[B^2_{pp}]$, or $[M^2_{pp}]$ respectively.

3. In addition to the header card containing IFØ, TIN and TØUT, a logical card consisting of two or more physical cards is needed for each nonnull column of the matrix.

4. If TIN = 1, Y_{ij} must be blank.

5. Field 3 of the header card must contain an interger 0.

6. For symmetric matrices, the entire matrix must be input.

7. Only nonzero terms need be entered.

8. There are a number of reserved words which may not be used for DMIAX names. Among these are PØØL, NPTP, ØPTP, UMF, NUMF, PLT1, PLT2, INPT, GEØM1, GEØM2, GEØM3, GEØM4, GEØM5, EDT, MPT, EPT, DIT, DYNAMICS, IFPFILE, AXIC, FØRCE, MATPØØL, PCDB, XYCDB, CASECC, any DTI names, and SCRATCH1 thru SCRATCH9.

Input Data Card DMIG   Direct Matrix Input at Grid Points

Description: Defines structure-related direct input matrices.

Format and Example:

1	2	3	4	5	6	7	8	9	10
DMIG	NAME	"0"	IFØ	TIN	TØUT				
DMIG	STIF	0	1	3	4				
DMIG	NAME	GJ	CJ		GI	CI	X_{ij}	Y_{ij}	Xabc
DMIG	STIF	27	1		2	3	3.+5	3.+3	EKG1
+abc	GI	CI	X_{ij}	Y_{ij}	GI	CI	X_{ij}	Y_{ij}	Xcef
+KG1	2	4	2.5+10	0.	50		1.0	0.	

etc. for each column containing nonzero terms

Field	Contents
NAME	BCD name of matrix (one to eight alphanumeric characters the first of which is alphabetic)
IFØ	1 Square matrix 2 General rectangular matrix 6 Symmetric matrix
TIN	Type of matrix being input as follows: 1 Real, single-precision (One field is used per element) 3 Complex, single-precision (Two fields are used per element)
TØUT	Type of matrix which will be created 1 Real, single-precision 3 Complex, single-precision 2 Real, double-precision 4 Complex, double-precision
GJ, GI	Grid or scalar or extra point identification number (Integer > 0)
CJ, CI	Component number for GJ a grid point ($0 < CJ \leq 6$); blank or zero for GJ a scalar or extra point
X_{ij}, Y_{ij}	Real and imaginary parts of matrix element

Remarks:
1. Matrices defined on this card may be used in dynamics by selection in the Case Control Deck by K2PP=NAME, B2PP=NAME, or M2PP=NAME for $[K^2_{pp}]$, $[B^2_{pp}]$, or $[M^2_{pp}]$, respectively.
2. In addition to the header card containing IFØ, TIN and TØUT, a logical card consisting of one or more physical cards is needed for each nonnull column of the matrix.
3. If TIN = 1, Y_{ij} must be blank.
4. Field 3 of the header card must contain an integer 0.
5. For symmetric matrices, the entire matrix must be input.
6. Only nonzero terms need be entered.
7. The matrix names must be unique among all DMIG's.

(Continued)

DMIG (Cont.)

8. There are a number of reserved words which may not be used for DMIG names. Among these are PØØL, NPTP, ØPTP, UMF, NUMF, PLT1, PLT2, INPT, GEØM1, GEØM2, GEØM3, GEØM4, GEØM5, EDT, MPT, EPT, DIT, DYNAMICS, IFPFILE, AXIC, FØRCE, MATPØØL, PCDB, XYCDB, CASECC, and DTI names, and SCRATCH1 thru SCRATCH9.

Input Data Card DPHASE Dynamic Load Phase Lead

Description: This card is used in conjunction with the RLØAD1 and RLØAD2 data cards to define the phase lead term θ in the equation of the loading function.

Format and Example:

1	2	3	4	5	6	7	8	9	10
DPHASE	SID	P	C	TH	P	C	TH		
DPHASE	4	21	6	2.1	8	6	7.2		

Field	Contents
SID	Identification number of DPHASE set (Integer > 0)
P	Grid or scalar point identification number (Integer > 0)
C	Component number (1-6 for grid point, 0 or blank for scalar point)
TH	Phase lead θ (in degrees) for designated coordinate (Real)

Remarks: One or two dynamic load phase lead terms may be defined on a single card.

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Input Data Card DPHASES   Dynamic Load Phase Lead - Substructure Analysis

Description: This card is used in conjunction with the RLØAD1 and RLØAD2 data cards to define the phase lead term θ in the equation of the loading function.

Format and Example:

1	2	3	4	5	6	7	8	9	10
DPHASES	SID	NAME	P	C	TH	P	C	TH	
DPHASES	4	SKIN	21	6	2.1	8	6	7.2	

Field	Contents
SID	Identification number of DPHASE set (Integer > 0)
NAME	Basic substructure name
P	Grid or scalar point identification number (Integer > 0)
C	Component number (1-6 for grid point, 0 or blank for scalar point)
TH	Phase lead θ (in degrees) for designated coordinate (Real)

Remarks:
1. One or two dynamic load phase lead terms may be defined on a single card.
2. Used in substructure SØLVE operation.
3. Points referenced must exist in the SØLVEd structure.

Input Data Card DSFACT Differential Stiffness Factor

Description: Used to define a scale factor for applied loads and stiffness matrix in a Normal Modes with Differential Stiffness Analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
DSFACT	SID	B							
DSFACT	97	-1.0							

Field	Contents
SID	Set identification number (Unique Integer > 0)
B	Scale factor (Real)

Remarks: 1. Load sets must be selected in the Case Control Deck (DSCØ=SID) to be used by NASTRAN.

2. All fields following the entry must be blank.

Input Data Card DTI Direct Table Input

Description: Used to define table data blocks directly.

Format and Example: (The first logical card is a header card)

1	2	3	4	5	6	7	8	9	10
DTI	NAME	"0"	T1	T2	T3	T4	T5	T6	+00
DTI	XXX	0	3	4	4096	32768	1	0	

+00	V	V		-etc.-	ENDREC				+01

-etc.-

DTI	NAME	IREC	V	V	V	V	V	V	+11
DTI	XXX	1	2.0	-6	ABC	6.0D0	-1	2	+11

+11	V	V	V	V	-etc.-		ENDREC		+12
+11	4	-6.2	2.9	1	DEF	-1	ENDREC		

-etc.-

Field	Contents
NAME	Any NASTRAN BCD value (1-8 alphanumeric characters, the first of which must be alphabetic) which will be used in the DMAP sequence to reference the data block
Ti	Trailer values (65535 $\geq$ Integer $\geq$ 0)
IREC	Record Number (sequential integer beginning with 1)
V	Value (blank, integer, real, BCD (except "ENDREC"), double precision)
ENDREC	The BCD value ENDREC which flags the end of the string of values that constitute logical record IREC

Remarks:

1. Records may be made as long as desired via continuation cards.
2. Values may be of any type (blank, integer, real, BCD, double precision) with the exception that a BCD value may not be "ENDREC".
3. All fields following ENDREC must be blank.
4. The user must write a DMAP (or make alterations to a rigid format) in order to use the DTI feature since he is defining a data block. All of the rules governing the use of data blocks in DMAP sequences apply.
5. The DMAP data block NAME (XXX in the example) will appear in the initial FIAT and the data block will initially appear on the PØØL.
6. If trailer is not specified, T1 = number of records, T2 thru T6 = 0.
7. In addition to the header card, there must be one logical card for each record in the table.

(Continued)

DTI (Cont.)

8. There are a number of reserved words which may not be used for DTI names. Among these are PØØL, NPTP, ØPTP, UMF, NUMF, PLT1, PLT2, INPT, GEØM1, GEØM2, GEØM3, GEØM4, GEØM5, EDT, MPT, EPT, DIT, DYNAMICS, IFPFILE, AXIC, FØRCE, MATPØØL, PCDB, XYCDB, CASECC, any DTI names, and SCRATCH thru SCRATCH9.

Input Data Card EIGB   Buckling Analysis Data

Description: Defines data needed to perform buckling analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
EIGB	SID	METHØD	L1	L2	NEP	NDP	NDN	E	+abc
EIGB	13	DET	0.1	2.5	2	1	1	0.0	ABC
+abc	NØRM	G	C						
+BC	MAX								

Field	Contents
SID	Set identification number (Unique Integer > 0)
METHØD	Method of eigenvalue extraction, one of the BCD values "INV", "DET","FEER", "UINV", or "UDET"
	INV - Inverse power method, symmetric matrix operations
	DET - Determinant method, symmetric matrix operations
	FEER - Tridiagonal reduction method, symmetric matrix operations
	UINV - Inverse power method, unsymmetric matrix operations
	UDET - Determinant method, unsymmetric matrix operations
L1,L2	Eigenvalue range of interest (Real; L1 < L2 > 0.0). For METHØD = "FEER", L1 is ignored and L2 is the acceptable relative error tolerance on eigenvalues, (Default is .1/n where n is the order of the stiffness matrix) (Real > 0.0)
NEP	Estimate of number of roots in positive range. Desired number of eigenvalues of smallest magnitude for METHØD = "FEER". (Default is automatically calculated to extract at least one accurate mode) (Integer > 0)
NDP,NDN	Desired number of positive and negative roots (Default = 3 NEP) (Integer > 0) Ignored for METHØD = "FEER"
E	Convergence criteria (optional) (Real > 0.0)
NØRM	Method for normalizing eigenvectors, one of the BCD values "MAX" or "PØINT"
	MAX - Normalize to unit value of the largest component in the analysis set
	PØINT - Normalize to unit value of the component defined in fields 3 and 4 (Defaults to "MAX" if defined component is zero)
G	Grid or scalar point identification number (Integer > 0) (Required if and only if NØRM = "PØINT")
C	Component number (One of the integers 1-6) (Required if and only if NØRM = "PØINT" and G is a geometric grid point)

(Continued)

Remarks: 1. Buckling analysis root extraction data sets must be selected in the Case Control Deck (METHØD = SID) to be used by NASTRAN.

2. The quantities L1 and L2 are dimensionless and specify a range in which the eigenvalues are to be found. An eigenvalue is a factor by which the prebuckling state of stress (first subcase) is multiplied to produce buckling. If METHØD = "FEER", L1 is ignored and L2 represents the maximum upper bound, in percent, on

$| \lambda_{FEER} / \lambda_{EXACT} - 1 |$ for acceptance of a computed eigensolution.

3. The continuation card is required.

4. See Sections 10.3.6 and 10.4.2.2 of the Theoretical Manual for a discussion of convergence criteria.

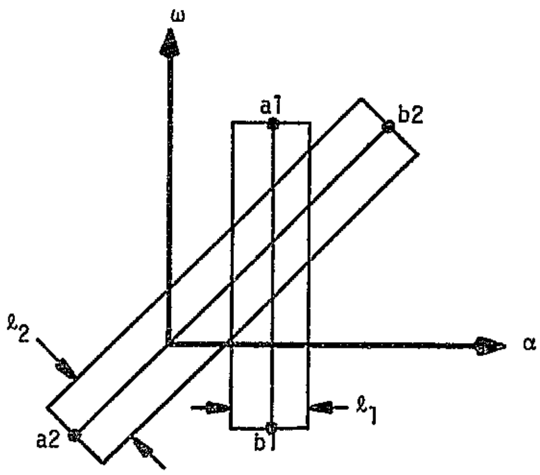
5. If METHØD = "DET", L1 must be greater than or equal to 0.0.

6. If NØRM = "MAX", components that are not in the analysis set may have values larger than unity.

7. If NØRM = "PØINT", the selected component must be in the analysis set.

Input Data Card EIGC Complex Eigenvalue Extraction Data

Description: Defines data needed to perform complex eigenvalue analysis.



Format and Example:

1	2	3	4	5	6	7	8	9	10
EIGC	SID	METHØD	NØRM	G	C	E			+abc
EIGC	14	DET	PØINT	27		1.-8			ABC
+abc	α_{a1}	ω_{a1}	α_{b1}	ω_{b1}	ℓ_1	N_{e1}	N_{d1}		+def
+BC	2.0	5.6	2.0	-3.4	2.0	4	4		DEF
+def	α_{a2}	ω_{a2}	α_{b2}	ω_{b2}	ℓ_2	N_{e2}	N_{d2}		
+EF	-5.5	-5.5	5.6	5.6	1.5	6	3		

(etc.)

Field	Contents
SID	Set identification number (Unique integer > 0)
METHØD	Method of complex eigenvalue extraction, one of the BCD values, "INV", "DET", "HESS", or "FEER" INV - Inverse power method DET - Determinant method HESS - Upper Hessenberg method FEER - Tridiagonal Reduction method

(Continued)

EIGC (Cont.)

NØRM	Method for normalizing eigenvectors, one of the BCD values "MAX" or "PØINT" MAX - Normalize to a unit value for the real part and a zero value for the imaginary part, the component having the largest magnitude PØINT - Normalize to a unit value for the real part and a zero value for the imaginary part the component defined in fields 5 and 6 - defaults to "MAX" if the magnitude of the defined component is zero.
G	Grid or scalar point identification number (Required if and only if NØRM=PØINT) (Integer > 0)
C	Component number (Required if and only if NØRM="PØINT" and G is a geometric grid point) ($0 \leq$ integer ≥ 6)
E	Convergence criterion (optional) (Real ≥ 0.0) For method = "FEER", error-tolerance on acceptable eigenvalues (default value is .10/n, where n is the order of the stiffness matrix).
$(\alpha_{aj}, \omega_{aj})$ $(\alpha_{bj}, \omega_{bj})$	Two complex points defining a line in the complex plane (Real) For method = "FEER", $(\alpha_{aj}, \omega_{aj})$ is a point of interest in the complex plane, closest to which the eigenvalues are computed; $\lvert\alpha_{aj}\rvert + \lvert\omega_{aj}\rvert > 0$. The point $(\alpha_{bj}, \omega_{bj})$ is ignored.
ℓj	Width of region in complex plane (Real > 0.0) Blank for method = "FEER'.
N_{ej}	Estimated number of roots in each region (Integer > 0) Ignored for method = "FEER".
N_{dj}	Desired number of roots in each region (Default is $3N_{ej}$) (Integer > 0) Desired number of accurate roots for method = "FEER" (Default is 1).

Remarks:

1. Each continuation card defines a rectangular search region. For method = "FEER", the card defines a circular search region, centered at $(\alpha_{aj}, \omega_{aj})$ and of sufficient radius to encompass N_{dj} roots. Any number of regions may be used and they may overlap. Roots in overlapping regions will not be extracted more than once.
2. Complex eigenvalue extraction data sets must be selected in the Case Control Deck (CMETHØD=SID) to be used by NASTRAN.
3. The units of α, ω and ℓ are radians per unit time.
4. At least one continuation card is required.
5. For the determinant method with no damping matrix, complex conjugates of the roots found are not printed.
6. See Section 10.4.4.5 of the Theoretical Manual for a discussion of convergence criteria.

(Continued)

7. For the Upper Hessenberg method, N_{d1} controls the number of eigenvectors computed. Only one continuation card is considered and the (α,ω) pairs, along with the parameters ℓ_1 and N_{e1}, are ignored. Insufficient storage for HESS will cause the program to switch to INV.

8. The error tolerance, E, for the "FEER" method is with regard to

$$\left| \frac{|\bar{p}_i - (\alpha_{aj}, \omega_{aj})|}{|p_i - (\alpha_{aj}, \omega_{aj})|} - 1 \right| \text{ for } [B] \neq [0] \text{ and}$$

$$\left| \frac{|\bar{p}_i^2 - (\alpha_{aj}, \omega_{aj})^2|}{|p^2 - (\alpha_{aj}, \omega_{aj})^2|} - 1 \right| \text{ for } [B] = [0],$$

where $\bar{p}_i$ is a computed eigenvalue and p_i an exact eigenvalue.

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Input Data Card EIGP Poles in Complex Plane

Description: Defines poles that are used in complex eigenvalue extraction.

Format and Example:

1	2	3	4	5	6	7	8	9	10
EIGP	SID	α	ω	M	α	ω	M		
EIGP	15	-5.2	0.0	2	6.3	5.5	3		

Field	Contents
SID	Set identification number (Integer > 0)
(α,ω)	Coordinates of point in complex plane (Real)
M	Multiplicity of complex root at pole defined by (α,ω) (Integer > 0)

Remarks:
1. Defines poles in complex plane that are used with associated EIGC card having same set number.
2. The units of α,ω are radians per unit time.
3. Poles are used only in the Determinant Method.
4. One or two poles may be defined on a single card.

Input Data Card EIGR Real Eigenvalue Extraction Data

Description: Defines data needed to perform real eigenvalue analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
EIGR	SID	METHØD	F1	F2	NE	ND	NZ	E	+abc
EIGR	13	DET	1.9	15.6	10	12	0	1.-3	ABC
+abc	NØRM	G	C						
+BC	PØINT	32	4						

Field

SID Set identification number (Unique integer > 0)

METHØD Method of eigenvalue extraction, one of the BCD values "INV", "DET", "GIV", "FEER", "UINV", or "UDET".

- INV - Inverse power method, symmetric matrix operations.
- DET - Determinant method, symmetric matrix operations.
- GIV - Givens method of tridiagonalization.
- FEER - Tridiagonal reduction method, symmetric matrix operations.
- UINV - Inverse power method, unsymmetric matrix operations.
- UDET - Determinant method, unsymmetric matrix operations.

F1,F2 Frequency range of interest (Required for METHØD = "DET", "INV", "UDET", or "UINV") (Real $\geq$ 0.0; F1 $\leq$ F2); If METHOD = GIV, frequency range over which eigenvectors are desired. The frequency range is ignored if ND > 0, in which case the eigenvectors for the first ND positive roots are found. (Real, F1 $\leq$ F2). If METHOD = "FEER", F1 is the center of range of interest (Default is F1 = 0.0) (Real $\geq$ 0.0), and F2 is the acceptable relative error tolerance on frequency-squared, (Default is .1/n where n is the order of the stiffness matrix) (Real > 0.0).

NE Estimate of number of roots in range (Required for METHØD = "DET", "INV", "UDET", or "UINV", ignored for METHØD = "GIV" and "FEER") (Integer > 0).

ND Desired number of roots for METHØD = "DET", "INV", "UDET", or "UNIV", (Default is 3 NE) (Integer > 0). Desired number of eigenvectors for METHØD = "GIV" (Integer > 0). Desired number of roots and eigenvectors for METHØD = "FEER" (Default is automatically calculated to extract at least one accurate mode) (Integer > 0).

NZ Number of free body modes (Optional - used only if METHØD = "DET" or "UDET") (Integer $\geq$ 0).

E Mass orthogonality test parameter (Default is 0.0 which means no test will be made) (Real $\geq$ 0.0).

(Continued)

NØRM	Method for normalizing eigenvectors, one of the BCD values "MASS", "MAX" or "PØINT" MASS - Normalize to unit value of the generalized mass MAX - Normalize to unit value of the largest component in the analysis set PØINT - Normalize to unit value of the component defined in fields 3 and 4 - defaults to "MAX" if defined component is zero
G	Grid or scalar point identification number (Required if and only if NØRM="PØINT") (Integer ≥ 0)
C	Component number (One of the integers 1-6) (Required if and only if NØRM="PØINT" and G is a geometric grid point)

Remarks:

1. Real eigenvalue extraction data sets must be selected in the Case Control Deck (METHØD = SID) to be used by NASTRAN.

2. The units of F1 and F2 are cycles per unit time. If METHØD = "FEER", F2 represents the maximum upper bound, in percent, on $|\omega^2_{FEER}/\omega^2_{EXACT} - 1|$ for acceptance of a computed eigensolution.

3. The continuation card is required.

4. If METHØD = "GIV", all eigenvalues are found.

5. If METHØD = "GIV", the mass matrix for the analysis set must be positive definite. This means that all degrees of freedom, including rotations, must have mass properties. ØMIT cards may be used to remove massless degrees of freedom.

6. A nonzero value of E in field 9 also modifies the convergence criteria. See Sections 10.3.6 and 10.4.2.2 of the Theoretical Manual for a discussion of convergence criteria.

7. If NØRM = "MAX", components that are not in the analysis set may have values larger than unity.

8. If NØRM = "PØINT", the selected component must be in the analysis set.

9. If METHØD = "GIV" and rigid body modes are present, F1 should be set to zero if the rigid body eigenvectors are desired.

10. The desired number of roots (ND) includes all roots previously found, such as rigid body modes determined with the use of the SUPØRT card, or the number of roots previously checkpointed when restarting and APPENDing the eigenvector file. The APPEND feature is available in the case of the Determinant, Inverse Power and FEER methods of eigenvalue extraction.

Input Data Card ENDDATA

Description: Defines the end of the Bulk Data Deck.

Format and Example:

1	2	3	4	5	6	7	8	9	10
ENDDATA									
ENDDATA									

First Alternate Form:

ENDATA									
ENDATA									

Second Alternate Form:

END DATA									
END DATA									

Remarks:

1. This card is required even if no physical data cards exist in the deck.

2. ENDDATA may begin in column 1 or 2. If the first alternate form is used, ENDATA may begin in column 1, 2 or 3. If the second alternate form is used, END DATA must necessarily begin in column 1.

3. Failure to include this card will result in job termination caused by an end-of-file condition being encountered on the input file.

4. Extraneous data cards may be stored after this card except when the INPUT module data follows or when the UMF card FINIS follows or when multiple job steps occur within the same job submittal on the CDC computer.

Input Data Card EPØINT Extra Point

Description: Defines extra points of the structural model for use in dynamics problems.

Format and Example:

1	2	3	4	5	6	7	8	9	10
EPØINT	ID	ID	ID	ID	ID	ID	ID	ID	
EPØINT	3	18	1	4	16	2			

Alternate Form

EPØINT	ID1	"THRU"	ID2						
EPØINT	17	THRU	43						

Field	Contents
ID,ID1,ID2	Extra point identification number (Integer > 0; ID1 < ID2)

Remarks: 1. All extra point identification numbers must be unique with respect to all other structural, scalar, and fluid points.

2. This card is used to define coordinates used in transfer function definitions (see TF card).

3. If the alternate form is used, extra points ID1 thru ID2 are defined.

Input Data Card FLFACT Aerodynamic Physical Data

Description: Used to specify densities, Mach numbers, and reduced frequencies for flutter analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
FLFACT	SID	F1	F2	F3	F4	F5	F6	F7	ABC
FLFACT	97	.3	.7	3.5					abc
+BC	F8	F9	--etc.--						

Alternate Form:

FLFACT	SID	F1	THRU	FNF	NF	FMID			
FLFACT	201	.200	THRU	.100	11	.133333			

Field	Contents
SID	Set identification number (Unique Integer > 0).
Fi	Aerodynamic factor (Real).

Remarks:

1. These factors must be selected by a FLUTTER data card to be used by NASTRAN.
2. Imbedded blank fields are forbidden.
3. Parameters must be listed in the order in which they are to be used within the looping of flutter analysis.
4. For the alternate form, NF must be greater than 1. F_{mid} must lie between F_1 and F_{NF}, otherwise F_{mid} will be set to $(F_1 + F_{NF})/2$. Then

$$F_i = \frac{F_1(F_{NF}-F_{mid})(NF-i) + F_{NF}(F_{mid}-F_1)(i-1)}{(F_{NF}-F_{mid})(NF-i) + (F_{mid}-F_1)(i-1)} \qquad i = 1,2,\ldots,NF$$

The use of F_{mid} (middle factor selection) allows unequal spacing of the factors. $F_{mid} = 2F_1F_{NF}/(F_1+F_{NF})$ gives equal values to increments of the reciprocal of F_i.

Input Data Card FLSYM Axisymmetric Symmetry Control

Description: Defines the relationship between the axisymmetric fluid and a structural boundary having symmetric constraints. The purpose is to allow fluid boundary matrices to conform to structural symmetry definitions.

Format and Example:

1	2	3	4	5	6	7	8	9	10
FLSYM	M	S1	S2						
FLSYM	12	S	A						

Field	Contents
M	Number of symmetric sections of structural boundary around circumference of fluid being modeled by the set of structural elements (Integer $\geq$ 2, even)
S1, S2	Description of boundary constraints used on structure at first and second planes of symmetry. (BCD: "S" => symmetric, "A" => antisymmetric)

Remarks:

1. This card is allowed only if an AXIF card is also present.
2. Only one (1) FLSYM card is allowed.
3. The card is not required if no planes of symmetry are involved.
4. First plane of symmetry is assumed to be at $\phi = 0$. Second plane of symmetry is assumed to be at $\phi = 360°/M$.
5. Symmetric and antisymmetric constraints for the structure must, in addition, be provided by the user.
6. The solution is performed for those harmonic indices listed on the AXIF card that are compatible with the symmetry conditions.

Example: If a quarter section of structure is used to model the boundary, M = 4. If the boundary constraints are S-S, the compatible cosine harmonics are: 0, 2, 4, etc. If S-A is used the compatible cosine harmonics are 1, 3, 5, ..., etc.

NASTRAN DATA DECK

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Input Data Card FLUTTER Aerodynamic Flutter Data

Description: Defines data needed to perform flutter analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
FLUTTER	SID	METHØD	DENS	MACH	RFREQ	IMETH	NVALUE	EPS	
FLUTTER	19	K	119	219	319	S	5	1.-4	

Field	Contents
SID	Set identification number (Unique Integer > 0).
METHØD	Flutter analysis method, "K" for K-method, "PK" for P-K method, "KE" for the K-method restricted for efficiency.
DENS	Identification number of an FLFACT data card specifying density ratios to be used in flutter analysis (Integer $\geq$ 0).
MACH	Identification number of an FLFACT data card specifying Mach numbers (m) to be used in flutter analysis (Integer $\geq$ 0).
RFREQ (or VEL)	Identification number of an FLFACT data card specifying reduced frequencies (k) to be used in flutter analysis (Integer > 0); for the p-k method, the velocity.
IMETH	Choice of interpolation method for matrix interpolation (BCD: L = linear, S = surface).
NVALUE	Number of eigenvalues for output and plots (Integer > 0).
EPS	Convergence parameter for k; used in the P-K method (Real)(default = 10^{-3}).

Remarks:

1. The FLUTTER data card must be selected in Case Control Deck (FMETHOD = SID).
2. The density is given by DENS • RHØREF, where RHØREF is the reference value given on the AERØ data card.
3. The reduced frequency is given by $k = (REFC \cdot \omega/2 \cdot V)$, where REFC is given on the AERØ data card, ω is the circular frequency and V is the velocity.
4. An eigenvalue is accepted in the P-K method when $|k - k_{estimate}| < EPS$.

Input Data Card FØRCE Static Load

Description: Defines a static load at a grid point by specifying a vector.

Format and Example:

1	2	3	4	5	6	7	8	9	10
FØRCE	SID	G	CID	F	N1	N2	N3		
FØRCE	2	5	6	2.9	0.0	1.0	0.0		

Field	Contents
SID	Load set identification number (Integer > 0)
G	Grid point identification number (Integer > 0)
CID	Coordinate system identification number (Integer ≥ 0)
F	Scale factor (Real)
N1,N2,N3	Components of Vector measured in coordinate system defined by CID (Real; $N1^2 + N2^2 + N3^2 > 0.0$)

Remarks: 1. The static load applied to grid point G is given by

$$\vec{f} = F\vec{N}$$

where $\vec{N}$ is the vector defined in fields 6, 7 and 8.

2. Load sets must be selected in the Case Control Deck (LOAD=SID) to be used by NASTRAN.

3. A CID of zero references the basic coordinate system.

Input Data Card FØRCE1 Static Load

Description: Used to define a static load by specification of a value and two grid points which determine the direction.

Format and Example:

1	2	3	4	5	6	7	8	9	10
FØRCE1	SID	G	F	G1	G2				
FØRCE1	6	13	-2.93	16	13				

Field	Contents
SID	Load set identification number (Integer > 0)
G	Grid point identification number (Integer > 0)
F	Value of load (Real)
G1, G2	Grid point identification numbers (Integer > 0; G1 ≠ G2)

Remarks: 1. The direction of the force is determined by the vector from G1 to G2.

2. Load sets must be selected in the Case Control Deck (LØAD=SID) to be used by NASTRAN.

Input Data Card FØRCE2 Static Load

Description: Used to define a static load by specification of a value and four grid points which determine the direction.

Format and Example:

1	2	3	4	5	6	7	8	9	10
FØRCE2	SID	G	F	G1	G2	G3	G4		
FØRCE2	6	13	-2.93	16	13	17	13		

Field	Contents
SID	Load set identification number (Integer > 0)
G	Grid point identification number (Integer > 0)
F	Value of load (Real)
G1,G2,G3,G4	Grid point identification numbers (Integer > 0; G1 ≠ G2; G3 ≠ G4)

Remarks: 1. The direction of the force is determined by the vector product whose factors are vectors from G1 to G2 and G3 to G4 respectively.

2. Load sets must be selected in the Case Control Deck (LØAD=SID) to be used by NASTRAN.

NASTRAN DATA DECK

Input Data Card FØRCEAX Axisymmetric Static Load

Description: Defines a static loading for a model containing CCØNEAX, CTRAPAX or CTRIAAX elements.

Format and Example:

1	2	3	4	5	6	7	8	9	10
FØRCEAX	SID	RID	HID	S	FR	FP	FZ		
FØRCEAX	1	2	3	2.0	0.1	0.2	0.3		

Field	Contents
SID	Load set identification number (Integer > 0)
RID	Ring identification number (see RINGAX) (Integer > 0)
HID	Harmonic identification number (Integer ≥ 0 or a sequence of harmonics, see note 4)
S	Scale factor for load (Real)
FR, FP, FZ	Load components in r, ϕ, z directions (Real)

Remarks:

1. This card is allowed if and only if an AXIC card is also present.
2. Axisymmetric loads must be selected in the Case Control Deck (LØAD=SID) to be used by NASTRAN.
3. A separate card is needed for the definition of the force associated with each harmonic.
4. If a sequence of harmonics is to be placed in HID the form is as follows: "Sn1Tn2" where n1 is the start of the sequence and n2 is the end of the sequence. i.e., harmonics 0 through 10, the field would contain "S0T10".
5. For a discussion of the conical shell problem, see Section 5.9 of the Theoretical Manual.
6. For a discussion of the axisymmetric solid problem see Section 5.11 of the Theoretical Manual.

Input Data Card FREEPT Fluid Free Surface Point

Description: Defines the location of points on the surface of a fluid for recovery of surface displacements in a gravity field.

Format and Example:

1	2	3	4	5	6	7	8	9	10
FREEPT	IDF		IDP	ϕ	IDP	ϕ	IDP	ϕ	
FREEPT	3		301	22.5	302	90.0	303	370.0	

Field	Contents
IDF	Fluid point (RINGFL) identification number (Integer > 0)
IDP	Free surface point identification number (Integer > 0)
ϕ	Azimuthal position of FREEPT on fluid point (RINGFL), in Fluid Coordinate System (Real)

Remarks:
1. This card is allowed only if an AXIF card is also present.
2. All free surface point identification numbers must be unique with respect to other scalar, structural and fluid points.
3. The free surface points are used for the identification of output data only.
4. Three points may be defined on a single card.
5. The referenced fluid point (IDF) must be included in a free surface list (FSLIST).
6. Output requests for velocity and acceleration can be made at these points.

Input Data Card FREQ Frequency List

Description: Defines a set of frequencies to be used in the solution of frequency response problems.

Format and Example:

1	2	3	4	5	6	7	8	9	10
FREQ	SID	F	F	F	F	F	F	F	abc
FREQ	3	2.98	3.05	17.9	21.3	25.6	28.8	31.2	ABC

+bc	F	F	F	F	F	F	F	F	
+BC	29.2	22.4	19.3						

-etc.-

Field	Contents
SID	Frequency set identification number (Integer > 0)
F	Frequency value (Real > 0.0)

Remarks:
1. The units for the frequencies are cycles per unit time.
2. Frequency sets must be selected in the Case Control Deck (FREQ=SID) to be used by NASTRAN.
3. All FREQ, FREQ1 and FREQ2 cards must have unique frequency set identification numbers.

Input Data Card FREQ1 Frequency List

Description: Defines a set of frequencies to be used in the solution of frequency response problems by specification of a starting frequency, frequency increment, and number of increments desired.

Format and Example:

1	2	3	4	5	6	7	8	9	10
FREQ1	SID	F1	DF	NDF					
FREQ1	6	2.9	0.5	13					

Field	Contents
SID	Frequency set identification number (Integer > 0)
F1	First frequency in set (Real ≥ 0.0)
DF	Frequency increment (Real > 0.0)
NDF	Number of frequency increments (Integer > 0)

Remarks:

1. The units for the frequency F1 and the frequency increment DF are cycles per unit time.
2. The frequencies defined by this card are given by

$$f_i = F1 + (i - 1)\,DF, \quad i = 1, NDF + 1$$

3. Frequency sets must be selected in the Case Control Deck (FREQ=SID) to be used by NASTRAN.
4. All FREQ, FREQ1 and FREQ2 cards must have unique frequency set identification numbers.

Input Data Card FREQ2 Frequency List

Description: Defines a set of frequencies to be used in the solution of frequency response problems by specification of a starting frequency, final frequency, and number of logarithmic increments desired.

Format and Example:

1	2	3	4	5	6	7	8	9	10
FREQ2	SID	F1	F2	NF					
FREQ2	6	1.0	1.E5	5					

Field	Contents
SID	Frequency set identification number (Integer > 0)
F1	First frequency (Real > 0.0)
F2	Last frequency (Real > 0.0; F2 > F1)
NF	Number of logarithmic intervals (Integer > 0)

Remarks:
1. The units for the frequencies F1 and F2 are cycles per unit time.
2. The frequencies defined by this card are given by

$$f_i = F1 \cdot e^{(i-1)d}, \qquad i = 1,2,\ldots,NF+1$$

where

$$d = \frac{1}{NF} \log_e \frac{F2}{F1}$$

For the example shown, the list of frequencies will be 1.0, 10.0, 100.0, 1000.0, 10000.0, and 100000.0 cycles per unit time.

3. Frequency sets must be selected in the Case Control Deck (FREQ=SID) to be used by NASTRAN.
4. All FREQ, FREQ1 and FREQ2 cards must have unique frequency set identification numbers.

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Input Data Card FSLIST   Free Surface List

Description: Declares the fluid points (RINGFL) which lie on a free surface boundary.

Format and Example:

1	2	3	4	5	6	7	8	9	10
FSLIST	RHØ	IDF1	IDF2	IDF3	IDF4	IDF5	IDF6	IDF7	abc
FSLIST	1.0-4	1	3	5	4	2	7	6	+12FS

+bc	IDF8	IDF9	-etc.-						def
+12FS	8	9	10	11	AXIS				

-etc.-

Field	Contents
RHØ	Mass density at the surface (Real > 0.0 or blank; if blank the AXIF default value must not be blank)
IDFi	Identification number of RINGFL point (Integer > 0 or BCD, "AXIS." The first and/or last entry may be AXIS)

Remarks:
1. This card is allowed only if an AXIF card is also present.
2. Each logical card defines a surface. The order of the points must be sequential with the fluid on the right with respect to the direction of travel.
3. The BCD word, AXIS, defines an intersection with the polar axis of the Fluid Coordinate System.
4. There may be as many FSLIST cards as the user requires. If the fluid density varies along the boundary there must be one FSLIST card for each interval between fluid points.

Input Data Card GEMLØØP - General Current Loop

Description: Defines a general current loop in magnetic field problems.

Format and Example:

1	2	3	4	5	6	7	8	9	10
GEMLØØP	SID	I	CID	X1	Y1	Z1	X2	Y2	+a
GEMLØØP	5	5.2	0	8.1	10.2	3.5	12.5	9.1	+A

+a	Z2	X3	Y3	Z3					+b
+A	1.3	ENDT							

Field	Contents
SID	Load set identification number (Integer > 0)
I	Current through loop (Real > 0.0)
CID	Coordinate system identification number (Integer > 0 or blank)
Xi,Yi,Zi	Coordinates of points defining linear sections of coil in coordinate system CID (Real)

Remarks:

1. Load sets must be selected in the Case Control Deck (LØAD=SID) to be used by NASTRAN.
2. In order for the coil to be closed, XN, YN, ZN must be equal to X1, Y1, Z1.
3. ENDT must be specified in the field immediately after ZN.
4. N should be such that $2 \le N \le 15$.
5. If a loop has more than 14 segments, another GEMLØØP card may be specified with the first point coincident with the last point of the previous card.
6. CID must presently be 0 or blank.

Input Data Card GENEL General Element

Description: Defines a general element using either:

1. The stiffness approach:

$$\begin{Bmatrix} f_i \\ \hline f_d \end{Bmatrix} = \left[\begin{array}{c|c} K & -KS \\ \hline -S^T K & S^T KS \end{array}\right] \begin{Bmatrix} u_i \\ \hline u_d \end{Bmatrix} \quad , \text{ or}$$

2. The flexibility approach:

$$\begin{Bmatrix} u_i \\ \hline f_d \end{Bmatrix} = \left[\begin{array}{c|c} Z & S \\ \hline -S^T & 0 \end{array}\right] \begin{Bmatrix} f_i \\ \hline u_d \end{Bmatrix} \quad , \text{ where}$$

$$\{u_i\} = [u_{i1}, u_{i2}, \ldots, u_{im}]^T \ ,$$

$$\{u_d\} = [u_{d1}, u_{d2}, \ldots, u_{dn}]^T \ ,$$

$$[KZ] = [K] \text{ or } [Z] = \begin{bmatrix} KZ_{11} & KZ_{12} & \cdots & KZ_{1m} \\ \vdots & KZ_{22} & \cdots & \vdots \\ \vdots & \vdots & & \vdots \\ KZ_{m1} & \cdots & \cdots & KZ_{mm} \end{bmatrix} \text{ and } [KZ]^T = [KZ] \ ,$$

$$[S] = \begin{bmatrix} S_{11} & \cdots & S_{1n} \\ \vdots & & \vdots \\ S_{m1} & \cdots & S_{mn} \end{bmatrix} .$$

The required input is the $\{u_i\}$ list and the lower triangular portion of [K] or [Z]. Additional input may include the $\{u_d\}$ list and [S]. If [S] is input, $\{u_d\}$ must also be input. If $\{u_d\}$ is input but [S] is omitted, [S] is internally calculated. In this case, $\{u_d\}$ must have six and only six degrees of freedom. If [S] is not required, both $\{u_d\}$ and [S] are omitted.

(Continued)

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GENEL (Cont.)

Format: (An example is given on the following page.)

1	2	3	4	5	6	7	8	9	10
GENEL	EID		UI1	CI1	UI2	CI2	UI3	CI3	X1
+1	UI4	CI4	UI5	CI5	UI6	CI6	UI7	CI7	X2
+2				Etc.					X3
+3	UI_m - The last item in the UI-list will appear in one of fields 2, 4, 6, or 8.								X4
+4	"UD"		UD1	CD1	UD2	CD2	UD3	CD3	X5
+5				Etc.					X6
+6	UD_n - The last item in the UD list will appear in one of fields 2, 4, 6, or 8.								X7
+7	"K" or "Z"	KZ11	KZ21	KZ31	Etc.		KZ22	KZ32	X8
+8	Etc.		KZ33	KZ43	Etc.				X9
+9				Etc.					X10
+10	KZ_{mm} - The last item in the K or Z matrix, will appear in one of fields 2 through 9.								X11
+11	"S"	S11	S12	Etc.		S21	Etc.		X12
+12	S_{mn} - The last item in the S matrix will appear in one of fields 2 through 9.								

Field	Contents
EID	Unique element identification number, a positive integer.
UI1, CI1 Etc. UD1, ED1 Etc.	Identification numbers of coordinates in the UI or UD list, in sequence corresponding to the [K], [Z], and [S] matrices. U_i and UD_i are grid point numbers, and CI_i and CD_i are the component numbers. If a scalar point is given, the component number is zero.
KZ_{ij}	Values of the [K] or [Z] matrix ordered by columns from the diagonal, according to the UI list.
S_{ij}	Values of the [S] matrix ordered by rows, according to the UD list.
"UD", "K", "Z", and "S"	BCD data words which indicate the start of data belonging to UD, [K], [Z], or [S].

Remarks: 1. When the stiffness matrix, K, is input, the number of significant digits should be the same for all terms.

2. Double-field format may be used for input of K or Z.

(Continued)

Example: Let element 629 be defined by

$$\{u_i\} = [1\text{-}1, 13\text{-}4, 42, 24\text{-}2]^T ,$$

$$\{u_d\} = [6\text{-}2, 33]^T ,$$

where i-j means the j^{th} component of grid point i. Points 42 and 33 are scalar points.

$$[K] = \begin{bmatrix} 1.0 & 2.0 & 3.0 & 4.0 \\ 2.0 & 5.0 & 6.0 & 7.0 \\ 3.0 & 6.0 & 8.0 & 9.0 \\ 4.0 & 7.0 & 9.0 & 0.0 \end{bmatrix} , \qquad [S] = \begin{bmatrix} 1.5 & 2.5 \\ 3.5 & 4.5 \\ 5.5 & 6.5 \\ 7.5 & 8.5 \end{bmatrix}$$

The data cards necessary to input this general element are shown below:

1	2	3	4	5	6	7	8	9	10
GENEL	629		1	1	13	4	42	0	X1
+1	24	2							X2
+2	UD		6	2	33	0			X3
+3	K	1.0	2.0	3.0	4.0	5.0	6.0	7.0	X4
+4	8.0	9.0	0.0						X5
+5	S	1.5	2.5	3.5	4.5	5.5	6.5	7.5	X6
+6	8.5								

Input Data Card GRAV Gravity Vector

Description: Used to define gravity vectors for use in determining gravity loading for the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
GRAV	SID	CID	G	N1	N2	N3			
GRAV	1	3	32.2	0.0	0.0	-1.0			

Field	Contents
SID	Set identification number (Integer > 0)
CID	Coordinate system identification number (Integer $\geq$ 0)
G	Gravity vector scale factor (Real)
N1, N2, N3	Gravity vector components (Real; $N1^2 + N2^2 + N3^2 > 0.0$)

Remarks: 1. The gravity vector is defined by

$$\vec{g} = G \cdot (N1, N2, N3).$$

2. A CID of zero references the basic coordinate system.

3. Gravity loads may be combined with "simple loads" (e.g., FØRCE, MØMENT) only by specification on a LØAD card. That is, the SID on a GRAV card may not be the same as that on a simple load card.

4. Load sets must be selected in the Case Control Deck (LØAD=SID) to be used by NASTRAN.

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Input Data Card GRDSET Grid Point Default

Description: Defines default options for fields 3, 7 and 8 of all GRID cards.

Format and Example:

1	2	3	4	5	6	7	8	9	10
GRDSET		CP				CD	PS		
GRDSET		16				32	3456		

Field	Contents
CP	Identification number of default coordinate system in which the locations of the grid points are defined (Integer ≥ 0)
CD	Identification number of default coordinate system in which displacements are measured at grid points (Integer ≥ 0)
PS	Permanent single-point constraints associated with grid point (any of the digits 1-6 with no imbedded blanks) (Integer ≥ 0)

Remarks:

1. The contents of fields 3, 7 or 8 of this card are assumed for the corresponding fields of any GRID card whose fields 3, 7 and 8 are blank. If any of these fields on the GRID card are blank, the default option defined by this card occurs for that field. If no permanent single-point constraints are desired or one of the coordinate systems is basic, the default may be overridden on the GRID card by making one of fields 3, 7 or 8 zero (rather than blank). Only one GRDSET card may appear in the user's Bulk Data Deck.
2. The primary purpose of this card is to minimize the burden of preparing data for problems with a large amount of repetition (e.g., two-dimensional pinned-joint problems).
3. At least one of the entries CP, CD, or PS must be nonzero.

Input Data Card GRID   Grid Point

Description: Defines the location of a geometric grid point of the structural model, the directions of its displacement, and its permanent single-point constraints.

Format and Example:

1	2	3	4	5	6	7	8	9	10
GRID	ID	CP	X1	X2	X3	CD	PS		
GRID	2	3	1.0	2.0	3.0		316		

Field	Contents
ID	Grid point identification number (0<Integer<999999)
CP	Identification number of coordinate system in which the location of the grid point is defined (Integer ≥ 0 or blank*).
X1,X2,X3	Location of the grid point in coordinate system CP (Real)
CD	Identification number of coordinate system in which displacements, degrees of freedom, constraints, and solution vectors are defined at the grid point (Integer ≥ 0 or blank*)
PS	Permanent single-point constraints associated with grid point (any of the digits 1-6 with no imbedded blanks) (Integer ≥ 0 or blank*)

Remarks:
1. All grid point identification numbers must be unique with respect to all other structural, scalar, and fluid points.
2. The meaning of X1, X2 and X3 depend on the type of coordinate system, CP, as follows: (see CØRD__ card descriptions)

Type	X1	X2	X3
Rectangular	X	Y	Z
Cylindrical	R	Θ(degrees)	Z
Spherical	R	Θ(degrees)	Φ(degrees)

3. The collection of all CD coordinate systems defined on all GRID cards is called the Global Coordinate System. All degrees-of-freedom, constraints, and solution vectors are expressed in the Global Coordinate System.

* See the GRDSET card for default options for fields 3, 7 and 8.

Input Data Card GRIDB Axisymmetric Problem Grid Point

Description: Defines the location of a geometric grid point on a RINGFL for an axisymmetric fluid model and/or axisymmetric structure. Used to define the boundary of the fluid.

Format and Example:

1	2	3	4	5	6	7	8	9	10
GRIDB	ID			ϕ		CD	PS	IDF	
GRIDB	30			30.0		3	345	20	

Field	Contents
ID	Grid point identification number (Integer > 0)
ϕ	Azimuthal position in the fluid in degrees (Real)
CD	Identification number of the coordinate system in which displacements are defined at the grid point (Integer $\geq$ 0)
PS	Permanent single-point constraints associated with the grid point (any combination of the digits 1-6 with no embedded blanks) (Integer $\geq$ 0)
IDF	Identification number of a RINGFL (Integer > 0)

Remarks:
1. This card is allowed only if an AXIF card is also present.
2. All GRIDB identification numbers must be unique with respect to other scalar, structural and fluid points.
3. An AXIF card must define a Fluid Coordinate System.
4. The RINGFL referenced must be present.
5. If no harmonic numbers on the AXIF card are specified, no fluid elements are necessary.
6. The collection of all CD coordinate systems defined on all GRID and GRIDB cards is called the Global Coordinate System.
7. Fields 3, 4, and 6 are ignored. This will facilitate the user's conversion of GRID cards to GRIDB cards. Note that the fields are the same except for fields 1 and 9 if a cylindrical coordinate system is used.
8. The referenced RINGFL point must be included in a boundary list (BDYLIST data card).

Input Data Card GRIDF Fluid Point

Description: Defines a scalar degree of freedom for harmonic analysis of a fluid.

Format and Example:

1	2	3	4	5	6	7	8	9	10
GRIDF	ID	R	Z						
GRIDF	23	2.5	-7.3						

Field	Contents
ID	Identification number of axisymmetric fluid point (Integer > 0)
R	Radial location of point in basic coordinate system (Real > 0.0)
Z	Axial location of point in basic coordinate system (Real)

Remarks:

1. This card is allowed only if an AXSLØT card is also present.

2. The identification number (ID) must be unique with respect to all other scalar, structural and fluid points.

3. Grid points on slot boundaries are defined on GRIDS cards. Do not also define them on GRIDF cards.

4. For plotting purposes the R location corresponds to the basic X coordinate. The Z location corresponds to the basic Y coordinate. Pressures will be plotted as displacement in the basic Z direction.

5. Load and constraint conditions are applied as if the GRIDF is a scalar point. Positive loads correspond to inward flow and a single point constraint causes zero pressure at the point.

Input Data Card GRIDS Slot Surface Point

Description: Defines a scalar degree of freedom with a two dimensional location. Used in defining pressure in slotted acoustic cavities.

Format and Example:

1	2	3	4	5	6	7	8	9	10
GRIDS	ID	R	Z	W	IDF				
GRIDS	25	2.5	-7.3	0.5					

Field	Contents
ID	Identification number of slot point (Integer > 0)
R	Radial location of point in basic coordinate system (Real $\neq$ 0.0)
Z	Axial location of point in basic coordinate system (Real)
W	Slot width or thickness at the GRIDS point (Real $\geq$ 0.0, or blank)
IDF	Identification number to define a GRIDF point (Integer > 0, or blank)

Remarks:

1. This card is allowed only if an AXSLØT card is also present.

2. The identification numbers (ID and IDF if present) must be unique with respect to all other scalar, structural and fluid points.

3. If W is "blank", the default value on the AXSLØT card will be used.

4. The IDF number is referenced on the CAXIFi card for central cavity fluid elements next to the interface. The IDF number is entered only if the grid point is on an interface. In this case it should not also be defined on a GRIDF card.

5. If IDF is nonzero then R must be greater than zero.

6. For plotting purposes the R location corresponds to the basic X coordinate. The Z location corresponds to the basic Y coordinate. The slot width, W, corresponds to the basic Z coordinate. The pressure will be plotted in the basic Z direction.

7 Load and constraint conditions are applied as if the GRIDS is a scalar point. Positive loads correspond to inward flow and a single point constraint causes zero pressure at the point.

Input Data Card GTRAN   Grid Point Transformation

Description: This card defines the output coordinate system transformation to be applied to the displacement set of a selected grid point.

Format and Example:

1	2	3	4	5	6	7	8	9	10
GTRAN	SID	NAME	GID	TRAN					
GTRAN	44	GIMBAL	1067	45					

Field	Contents
SID	Identification number of the transformation set (Integer > 0)
NAME	Basic substructure name (BCD)
GID	Grid point identification (Integer > 0)
TRAN	Identification number of a TRANS bulk data card (Integer ≥ 0)

Remarks: 1. If TRAN = 0, the displacement set at the grid point will be transformed to the overall basic coordinate system.

2. If TRAN = SID, the point will remain fixed to the substructure (i.e., no transformation occurs).

3. Otherwise, the displacement set at the grid point will be transformed to the coordinate system directions defined by the selected TRANS card.

4. Transformation sets must be selected in the Substructure Control Deck (TRAN=SID) to be used by NASTRAN. Note that 'TRAN' is a subcommand of the substructure CØMBINE command.

Input Data Card GUST Aerodynamic Gust Load Description

Description: Defines a stationary vertical gust for use in aeroelastic analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
GUST	SID	DLØAD	WG	XO	V				
GUST	133	61	1.0	0.	1.+4				

Field	Contents
SID	Gust set identification number (Integer > 0).
DLØAD	The SID of a TLØAD or RLØAD data card which defines the time or frequency dependence (Integer > 0).
WG	Scale factor (gust velocity/forward velocity) for gust velocity (Real $\neq$ 0.).
XO	Location of reference plane in aerodynamic coordinates (Real $\geq$ 0.0).
V	Velocity of vehicle (Real > 0.0).

Remarks:

1. The GUST card is selected in Case Control by GUST=SID.
2. The gust angle is in the +z direction of the aerodynamic coordinate system. The value is

$$WG \cdot T\left(t - \frac{x-x_0}{V}\right) \quad ,$$

where T is the tabular function.

3. In random analysis, a unit gust velocity (WG=1/velocity) is suggested. The actual rms value is entered on the TABRNDG data card.
4. XO and V may not change between subcases under one execution.

Input Data Card LØAD Static Load Combination (Superposition)

Description: Defines a static load as a linear combination of load sets defined via FØRCE, MØMENT, FØRCE1, MØMENT1, FØRCE2, MØMENT2, PLØAD, PLØAD2, PLØAD3, FØRCEAX, PRESAX, MØMAX, SLØAD, RFØRCE and GRAV cards.

Format and Example:

1	2	3	4	5	6	7	8	9	10
LØAD	SID	S	S1	L1	S2	L2	S3	L3	abc
LØAD	101	-0.5	1.0	3	6.2	4			
+bc	S4	L4		-etc.-					

(etc.)

Field	Contents
SID	Load set identification number (Integer > 0)
S	Scale factor (Real)
Si	Scale factors (Real)
Li	Load set identification numbers defined via card types enumerated above (Integer > 0)

Remarks: 1. The load vector defined is given by

$$\{P\} = S\sum_i S_i \{P_{Li}\}$$

2. The SID on a LØAD card must be unique and must be different from the load set identification numbers of all external static load sets in the Bulk Data Deck.

3. The Li must be unique. The remainder of the physical card containing the last entry must be blank.

4. This card must be used if gravity loads (GRAV) are to be used with any of the other types.

5. Load sets must be selected in the Case Control Deck (LØAD=SID) to be used by NASTRAN.

6. A LØAD card may not reference a set identification number defined by another LØAD card.

Input Data Card LØADC Substructure Static Loading Combination

Description: Defines the static load for a substructuring analysis as a linear combination of load sets defined for each basic substructure.

Format and Example:

1	2	3	4	5	6	7	8	9	10
LØADC	SID	S	NAME1	ID1	S1	NAME2	ID2	S2	abc
LØADC	27	1.0	WINGRT	5	0.5	FUSELAGE	966	2.5	ABC
+bc			NAME3	ID3	S3	NAME4	ID4	S4	def
+BC			MIDWG	27	1.75	etc.			

Field	Contents
SID	Load set identification number (Integer > 0)
S	Scale factor applied to final load vector (Real)
NAMEi	Basic substructure name (BCD)
IDi	Load set identification number of substructure NAMEi (Integer > 0)
Si	Scale factor (Real)

Remarks: 1. The load vector is combined by:

$$\{P\} = S\sum_i Si\ \{P\}_{IDi}$$

2. The load set identification numbers (IDi) reference the load sets used in Phase 1 to generate the load vectors on the basic substructures.

3. The NAMEi and IDi need not be unique.

4. The LØADC card is the means of specifying a static loading condition in a Phase 2 substructure analysis. The IDi may actually reference temperature loads or element deformation loads defined in Phase 1.

5. Load sets must be selected in the Case Control Deck (LØAD=SID) to be used by NASTRAN.

Input Data Card MAT1 Material Property Definition

Description: Defines the material properties for linear, temperature-independent, isotropic materials.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MAT1	MID	E	G	NU	RHØ	A	TREF	GE	+abc
MAT1	17	3.+7	1.9+7		4.28	0.19	5.37+2	0.23	ABC
+abc	ST	SC	SS	MCSID					
+BC	20.+4	15.+4	12.+4	2004					

Field	Contents
MID	Material identification number (Integer > 0)
E	Young's modulus (Real ≥ 0.0 or blank)
G	Shear modulus (Real ≥ 0.0 or blank)
NU	Poisson's ratio (-1.0 < Real ≤ 0.5 or blank)
RHØ	Mass density (Real)
A	Thermal expansion coefficient (Real)
TREF	Thermal expansion reference temperature (Real)
GE	Structural element damping coefficient (Real)
ST, SC, SS	Stress limits for tension, compression and shear (Real) (Required for Property Optimization calculations; otherwise optional if margins of safety are desired.)
MCSID	Material coordinate system identification number (Integer ≥ 0 or blank)

Remarks:

1. One of E or G must be positive (i.e., either E > 0.0 or G > 0.0 or both E and G may be > 0.0).
2. If any one of E, G or NU is blank, it will be computed to satisfy the identity $E = 2(1+NU)G$; otherwise, values supplied by the user will be used.
3. The material identification number must be unique for all MAT1, MAT2 and MAT3 cards.
4. MAT1 materials may be made temperature dependent by use of the MATT1 card and stress dependent by use of the MATS1 card.
5. The mass density, RHØ, will be used to automatically compute mass for all structural elements except the two-dimensional bending only elements TRBSC, TRPLT and QDPLT.
6. If E and NU or G and NU are both blank they will be both given the value 0.0.
7. Weight density may be used in field 6 if the value $\frac{1}{g}$ is entered on the PARAM card WTMASS, where g is the acceleration of gravity.
8. Solid elements must not have NU equal to 0.5.
9. Entries for A (thermal expansion coefficient) and TREF (reference temperature) are assumed to be 0.0 when blank. In a heat formulation, A must be overridden by an appropriate entry; TREF may be overridden if desired.
10. MCSID (> 0) is required if stresses or strains/curvatures are to be computed in a material coordinate system. This is applicable only for TRIA1, TRIA2, QUAD1, and QUAD2 elements.

Input Data Card MAT2 Material Property Definition

Description: Defines the material properties for linear, temperature-independent, anisotropic materials.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MAT2	MID	G11	G12	G13	G22	G23	G33	RHO	+abc
MAT2	13	6.2+3			6.2+3		5.1+3	0.056	ABC
+abc	A1	A2	A12	TO	GE	ST	SC	SS	+def
+BC	0.15			-500.0	0.002	20.+5			DEF
+def	MCSID								
+EF	1008								

Field	Contents
MID	Material identification number (Integer > 0)
Gij	The material property matrix (Real)
RHØ	Mass density (Real)
Ai	Thermal expansion coefficient vector (Real)
TO	Thermal expansion reference temperature (Real)
GE	Structural element damping coefficient (Real)
ST, SC, SS	Stress limits for tension, compression and shear (Real) (Used only to compute margins of safety in certain elements; they have no effect on the computational procedures)
MCSID	Material coordinate system identification number (Integer ≥ 0 or blank)

Remarks:

1. The material identification numbers must be unique for all MAT1, MAT2 and MAT3 cards.
2. MAT2 materials may be made temperature dependent by use of the MATT2 card.
3. The mass density, RHØ, will be used to automatically compute mass for all structural elements except the two-dimensional bending only elements TRBSC, TRPLT and QDPLT.
4. The convention for the G_{ij} in fields 3 through 8 is represented by the matrix relationship.

$$\begin{Bmatrix} \sigma_1 \\ \sigma_2 \\ \tau_{12} \end{Bmatrix} = \begin{bmatrix} G_{11} & G_{12} & G_{13} \\ G_{12} & G_{22} & G_{23} \\ G_{13} & G_{23} & G_{33} \end{bmatrix} \begin{Bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \gamma_{12} \end{Bmatrix}$$

5. MCSID (> 0) is required if stresses or strains/curvatures are to be computed in a material coordinate system. This is applicable only for TRIA1, TRIA2, QUAD1, and QUAD2 elements.

Input Data Card MAT3 Material Property Definition

Description: Defines the material properties for linear, temperature-independent, orthotropic materials.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MAT3	MID	EX	EY	EZ	NUXY	NUYZ	NUZX	RHØ	+abc
MAT3	23	1.0+7	1.1+7	1.2+7	.3	.25	.27	1.0-5	ABC
+abc	GXY	GYZ	GZX	AX	AY	AZ	TREF	GE	
+BC	2.5+6	3.0+6	2.5+6	1.0-4	1.0-4	1.1-4	68.5	.23	

Field	Contents
MID	Material identification number (Integer > 0)
EX, EY, EZ	Young's moduli in the x, y and z directions respectively (Real ≥ 0.0)
NUXY,NUYZ,NUZX	Poisson's Ratios (Coupled strain ratios in the xy, yz and zx directions respectively) (Real)
RHØ	Mass density (Real)
GXY, GYZ, GZX	Shear moduli for xy, yz and zx (Real ≥ 0.0)
AX, AY, AZ	Thermal expansion coefficients (Real)
TREF	Thermal expansion reference temperature (Real)
GE	Structural element damping coefficient (Real)

Remarks:

1. The material identification number must be unique with respect to the collection of all MATi cards.
2. MAT3 materials may be made temperature-dependent by use of the MATT3 card.
3. All nine of the numbers EX, EY, EZ, NUXY, NUYZ, NUZX, GXY, GYZ and GZX must be present.
4. A nonfatal warning diagnostic will occur if any of NUXY or NUYZ has an absolute value greater than 1.0.
5. MAT3 materials may only be referenced by CTRIARG, CTRAPRG, CTRIAAX, CTRAPAX, and PTØRDRG cards.
6. The mass density, RHØ, will be used to automatically compute mass for the TRIARG, TRAPRG, CTRIAAX, CTRAPAX and TØRDRG elements.

Input Data Card MAT4 Thermal Material Property Definition

Description: Defines the thermal material properties for temperature-independent, isotropic materials.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MAT4	MID	K	CP						
MAT4	103	.6	.2						

Field	Contents
MID	Material identification number (Integer > 0)
K	Thermal conductivity (Real > 0.0), or convective film coefficient
CP	Thermal capacity per unit volume (Real > 0.0 or blank), or film capacity per unit area

Remarks:

1. The material identification number may be the same as a MAT1, MAT2, or MAT3 card, but must be unique with respect to other MAT4 or MAT5 cards.
2. If a HBDY element references this card, K is the convective film coefficient and CP is the thermal capacity per unit area.
3. MAT4 materials may be made temperature dependent by use of the MATT4 card.

Input Data Card MAT5 Thermal Material Property Definition

Description: Defines the thermal material properties for temperature-independent, anisotropic materials.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MAT5	MID	KXX	KXY	KXZ	KYY	KYZ	KZZ	CP	
MAT5	24	.092			.083		.020	0.2	

Field	Contents
MID	Material identification number (Integer > 0)
KXX,KXY,KXZ, KYY,KYZ,KZZ	Thermal conductivity matrix terms (Real)
CP	Thermal capacity per unit volume (Real $\geq$ 0.0 or blank)

Remarks:

1. The thermal conductivity matrix has the form:

$$K = \begin{bmatrix} KXX & KXY & KXZ \\ KXY & KYY & KYZ \\ KXZ & KYZ & KZZ \end{bmatrix}$$

2. The material number may be the same as a MAT1, MAT2, or MAT3 card, but must be unique with respect to the MAT4 or MAT5 cards.

3. MAT5 materials may be made temperature dependent by use of the MATT5 card.

Input Data Card MAT6 - Material Property Definition

Description: Defines the material properties for linear, temperature-independent, anisotropic materials for solid isoparametric elements.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MAT6	MID	G11	G12	G13	G14	G15	G16	G22	+a
MAT6	31	0.23+7	-0.21+7	0.32+6	0.16+7	0.11+7	0.53+6	0.74+7	+A
+a	G23	G24	G25	G26	G33	G34	G35	G36	+b
+A	-0.21+7	-0.55+7	-0.37+7	-0.18+7	0.23+7	0.16+7	0.11+7	0.53+6	+B
+b	G44	G45	G46	G55	G56	G66	RHØ	AXX	+c
+B	0.66+7	0.28+7	0.14+7	0.43+7	0.92+6	0.30+7	7.32-4		
+c	AYY	AZZ	AXY	AYZ	AZX	TREF	GE		

Field	Contents
MID	Material property identification number (Integer > 0)
Gij	Symmetric portion of 6x6 material matrix (Real)
RHØ	Mass density (Real)
Aij	Thermal expansion coefficient vector (Real)
TREF	Thermal expansion reference temperature (Real)
GE	Structural damping coefficient (Real)

Remarks:

1. The material property identification number must be unique with respect to all other material cards.
2. MAT6 materials may be made temperature-dependent by use of the MATT6 card.
3. The ordering of the rows and columns of the matrix is critical and must conform to NASTRAN's ordering of the stress and strain vectors.

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Input Data Card MATF - Fluid Material Property Definition

Description: Defines the fluid density in a hydroelastic analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MATF	MID	RHØ							
MATF	103	0.6							

Field	Contents
MID	Material identification number (Integer > 0)
RHØ	Mass density (Real > 0.0)

Remark: 1. The material identification number may be the same as that of a MAT1, MAT2 or MAT3 card, but must be unique with respect to other MATF cards.

Input Data Card MATPZ1 - Piezoelectric Material Property Definition

Description: Defines the material properties for linear, temperature-independent piezoelectric materials.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MATPZ1	MID	s^E_{11}	s^E_{33}	s^E_{44}	s^E_{12}	s^E_{13}	d_{31}	d_{33}	+a
MATPZ1	1	12.3	15.5	39.0	-4.05	-5.31	-123.0	289.0	+A

+a	d_{15}	$\varepsilon^S_{11}/\varepsilon_0$	$\varepsilon^S_{33}/\varepsilon_0$	RHØ	A	TREF	GE	X	
+A	496.0	730.0	635.0	7500.0					

Field	Contents
MID	Material identification number (Integer > 0)
s^E_{11} thru d_{15}	Piezoelectric constants multiplied by 10^{12} (Real)
$\varepsilon^S_{11}/\varepsilon_0$, $\varepsilon^S_{33}/\varepsilon_0$	Piezoelectric constants, where ε_0 is taken to be 8.854×10^{-12} farad/meter (Real)
RHØ	Mass density (Real)
A	Thermal expansion coefficient (Real)
TREF	Thermal expansion reference temperature (Real)
GE	Structural element damping coefficient (Real)

Remarks:

1. MID must be unique with respect to all other material cards.
2. MATPZ1 materials may be made temperature-dependent by use of the MTTPZ1 card.
3. MATPZ1 may be referenced only by PTRAPAX and PTRIAAX cards.
4. Matrix [s^E] must be nonsingular.

Input Data Card MATPZ2 - Piezoelectric Material Property Definition

Description: Defines the material properties for linear, temperature-independent, piezoelectric materials.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MATPZ2	MID	c^E_{11}	c^E_{12}	c^E_{13}	c^E_{14}	c^E_{15}	c^E_{16}	c^E_{22}	+a
MATPZ2	23	1.	2.	3.	4.	5.	6.	1.	+A
+a	c^E_{23}	c^E_{24}	c^E_{25}	c^E_{26}	c^E_{33}	c^E_{34}	c^E_{35}	c^E_{36}	+b
+A	2.	3.	4.	5.	1.	2.	3.	4.	+B
+b	c^E_{44}	c^E_{45}	c^E_{46}	c^E_{55}	c^E_{56}	c^E_{66}	e_{11}	e_{12}	+c
+B	1.	2.	3.	1.	2.	1.	1.	2.	+C
+c	e_{13}	e_{14}	e_{15}	e_{16}	e_{21}	e_{22}	e_{23}	e_{24}	+d
+C	3.	4.	5.	6.	1.	2.	3.	4.	+D
+d	e_{25}	e_{26}	e_{31}	e_{32}	e_{33}	e_{34}	e_{35}	e_{36}	+e
+D	5.	6.	1.	2.	3.	4.	5.	6.	+E
+e	ε^S_{11}	ε^S_{12}	ε^S_{13}	ε^S_{22}	ε^S_{23}	ε^S_{33}	RHØ	AX	+f
+E	1.	2.	3.	4.	5.	6.	.15	6.-7	+F
+f	AY	AZ	TREF	GE					
+F	6.-7	6.-7	70.	.2					

(Continued)

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MATPZ2 (Cont.)

Field	Contents
MID	Material identification number (Integer > 0)
c^E_{11} thru ε^S_{33}	Piezoelectric constants (Real)
RHØ	Mass density (Real)
AX,AY,AZ	Thermal expansion coefficients (Real)
TREF	Thermal expansion reference temperature (Real)
GE	Structural element damping coefficient (Real)

Remarks:
1. MID must be unique with respect to all other material cards.
2. MATPZ2 materials may be made temperature-dependent by use of the MTTPZ2 card.
3. MATPZ2 may be referenced only by PTRAPAX and PTRIAAX cards.
4. See CAUTION discussed in Section 1.17.3.2.

Input Data Card MATS1 Material Stress Dependence

Description: Specifies table references for material properties on a MAT1 card that are stress-dependent.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MATS1	MID	R1							+abc
MATS1	17	28							ABC

Field	Contents
MID	Material property identification number which matches the identification number on some basic MAT1 card (Integer > 0)
R1	Reference to table identification number (Integer $\geq$ 0 or blank)

Remarks: 1. A blank or zero entry means no table dependence of the referenced quantity, E, on the basic MAT1 card. For this case, the MATS1 card is not required.

2. TABLES1 type tables must be used.

Input Data Card MATT1 Material Temperature Dependence

Description: Specifies table references for isotropic material properties on a MAT1 card that are temperature-dependent.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MATT1	MID	R1	R2	R3	R4	R5	R6	R7	+abc
MATT1	17	32				15			ABC
+abc	R8	R9	R10						
+BC	62								

Field	Contents
MID	Material property identification number which matches the identification number on some basic MAT1 card (Integer > 0)
Ri	References to table identification numbers (Integer $\geq$ 0 or blank) for the corresponding fields on the MAT1 card

Remarks:

1. Blank or zero entries mean no table dependence of the referenced quantity on the basic MAT1 card, and the quantity remains constant.
2. TABLEM1, TABLEM2, TABLEM3 or TABLEM4 type tables may be used.
3. Material properties given on a basic MATi card are initial values. If two or more quantities are to retain a fixed relationship, then two or more (as required) tables must be input to define the relationship.

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Input Data Card MATT2 Material Temperature Dependence

Description: Specifies table references for anisotropic material properties on a MAT2 card that are temperature-dependent.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MATT2	MID	R1	R2	R3	R4	R5	R6	R7	+abc
MATT2	17	32				15			ABC
+abc	R8	R9	R10	R11	R12	R13	R14	R15	
+BC	62								

Field	Contents
MID	Material property identification number which matches the identification number on some basic MAT2 card (Integer > 0)
Ri	References to table identification numbers (Integer ≥ 0 or blank) for the corresponding fields on the MAT2 card

Remarks:

1. Blank or zero entries mean no table dependence of the referenced quantity on the basic MAT2 card, and the quantity remains constant.
2. TABLEM1, TABLEM2, TABLEM3 or TABLEM4 type tables may be used.
3. Material properties given on a basic MATi card are initial values. If two or more quantities are to retain a fixed relationship, then two or more (as required) tables must be input to define the relationship.

Input Data Card MATT3 Material Temperature Dependence

Description: Specifies table references for orthotropic material properties on a MAT3 card that are temperature-dependent.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MATT3	MID	R1	R2	R3	R4	R5	R6	R7	+abc
MATT3	23	48			54				ABC
+abc	R8	R9	R10	R11	R12	R13	R14	R15	
+BC	74								

Field	Contents
MID	Material property identification number which matches the identification number on some basic MAT3 card (Integer > 0)
Ri	References to table identification numbers (Integer $\geq$ 0 or blank) for the corresponding fields on the MAT3 card

Remarks:

1. Blank or zero entries imply no table dependence of the referenced quantity on the basic MAT3 card, and the quantity remains constant.
2. TABLEM1, TABLEM2, TABLEM3 or TABLEM4 type tables may be used.
3. Material properties given on a basic MATi card are initial values. If two or more quantities are to retain a fixed relationship, then two or more (as required) tables must be input to define the relationship.

Input Data Card MATT4 Thermal Material Temperature Dependence

Description: Specifies table reference for temperature dependent thermal conductivity or convective film coefficient on a MAT4 card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MATT4	MID	T(K)							
MATT4	103	73							

Field	Contents
MID	ID of a MAT4 which is to be temperature dependent (Integer > 0)
T(K)	Identification number of a TABLEMi card which gives temperature dependence of the thermal conductivity or convective film coefficient (Integer ≥ 0 or blank)

Remarks: 1. The thermal capacity may not be temperature dependent; field 4 must be blank.

2. TABLEM1, TABLEM2, TABLEM3, or TABLEM4 type tables may be used. The basic quantity, K, on the MAT4 card is always multiplied by the tabular function. Note that this is different from structural applications.

3. A blank or zero entry means no table dependence of the referenced quantity on the basic MAT4 card. For this case, the MATT4 card is not required.

Input Data Card MATT5   Thermal Material Temperature Dependence

Description: Specifies table references for thermal conductivity matrix terms on a MAT5 card that are temperature-dependent.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MATT5	MID	T(KXX)	T(KXY)	T(KXZ)	T(KYY)	T(KYZ)	T(KZZ)		
MATT5	24	73							

Field	Contents
MID	Identification number of a MAT5, which is to be temperature dependent (Integer > 0)
T(K--)	Identification number of a TABLEMi card which gives temperature dependence of the matrix term (Integer $\geq$ 0 or blank)

Remarks:

1. The thermal capacity may not be temperature dependent. Field 9 must be blank.
2. TABLEM1, TABLEM2, TABLEM3, or TABLEM4 type tables may be used. The basic quantities on the MAT5 card are always multiplied by the tabular function. Note that this is different from the structural applications.
3. Blank or zero entries mean no table dependence of the referenced quantity on the basic MAT5 card, and the quantity remains constant.
4. Material properties given on a basic MATi card are initial values. If two or more quantities are to retain a fixed relationship, then two or more (as required) tables must be input to define the relationship.

Input Data Card MATT6 - Material Temperature Dependence

Description: Specifies table references for material properties on a MAT6 card that are temperature-dependent.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MATT6	MID	R1	R2	R3	R4	R5	R6	R7	+a
MATT6	115	101	102	103	104	105	106	107	+A
+a	R8	R9	R10	R11	R12	R13	R14	R15	+b
+A	108	109	110	111	112	113	114	115	+B
+b	R16	R17	R18	R19	R20	R21	R22	R23	+c
+B	116	117	118	119	120	121	122	123	+C
+c	R24	R25	R26	R27	R28	R29	R30		
+C	124	125	126	127	128	129	130		

Field	Contents
MID	Material property identification number which matches the identification number on some basic MAT6 card (Integer > 0)
Ri	References to table identification numbers (Integer ≥ 0 or blank)

Remarks: 1. Blank or zero entries mean no table dependence of the referenced quantity on the basic MAT6 card.

2. TABLEM1, TABLEM2, TABLEM3 and TABLEM4 type tables may be used.

Input Data Card MDIPØLE - Magnetic Dipole Moment

Description: Defines a magnetic dipole moment in magnetic field problems.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MDIPØLE	SID	CID	CX	CY	CZ	MX	MY	MZ	+a
MDIPØLE	5		1.0	2.0	3.0	10.0	20.0	30.0	+A

+a	MIN	MAX							
+A	0.0	0.0							

Field	Contents
SID	Load set identification number (Integer > 0)
CID	Coordinate system identification number (Integer > 0)
CX,CY,CZ	Coordinates of location of dipole in coordinate system CID (Real)
MX,MY,MZ	Components of magnetic dipole moment in coordinate system CID (Real)
MIN	Minimum distance from dipole to grid point for computing magnetic equivalent loads (Real > 0.0)
MAX	Maximum distance from dipole to grid point for computing magnetic equivalent loads (Real > 0.0)

Remarks:

1. Load sets must be selected in the Case Control Deck (LØAD=SID) to be used by NASTRAN.
2. Presently, CID must be blank or zero, indicating the basic coordinate system.
3. MIN and MAX represent minimum and maximum distances, respectively, from the dipole to a point outside of which the magnetic equivalent loads will not be computed for this dipole. If MAX is zero or blank, loads for all necessary points beyond the MIN distance will be computed.
4. The continuation card is required.

Input Data Card MKAERØ1 Mach Number - Frequency Table

Description: Provides a table of Mach numbers (m) and reduced frequencies (k) for aerodynamic matrix calculation.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MKAERØ1	m_1	m_2	m_3	m_4	m_5	m_6	m_7	m_8	ABC
MKAERØ1	.1	.7							+ABC
+BC	k_1	k_2	k_3	k_4	k_5	k_6	k_7	k_8	
+BC	.3	.6	1.0						

Field	Contents
m_i	List of Mach numbers (Real; $1 \leq i \leq 8$).
k_j	List of reduced frequencies (Real > 0.0, $1 \leq j \leq 8$).

Remarks:

1. Blank fields end the list, and thus cannot be used for 0.0.
2. All combinations of (m,k) will be used.
3. The continuation card is required.
4. Since 0.0 is not allowed, it may be simulated with a very small number such as 0.0001.

Input Data Card MKAERØ2 Mach Number - Frequency Table

Description: Provides a list of Mach numbers (m) and reduced frequencies (k) for aerodynamic matrix calculation.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MKAERØ2	m_1	k_1	m_2	k_2	m_3	k_3	m_4	k_4	
MKAERØ2	.10	.30	.10	.60	.70	.30	.70	1.0	

Field	Contents
m_i	List of Mach numbers (Real > 0.0).
k_i	List of reduced frequencies (Real > 0.0).

Remarks:

1. This card will cause the aerodynamic matrices to be computed for a set of parameter pairs.
2. Several MKAERØ2 cards may be in the deck.
3. Imbedded blank pairs are skipped.

NASTRAN DATA DECK

Input Data Card MØMAX Conical Shell Static Moment

Description: Defines a static moment loading of a conical shell coordinate.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MØMAX	SID	RID	HID	S	MR	MP	MZ		
MØMAX	1	2	3	1.0	0.1	0.2	0.3		

Field	Contents
SID	Load set identification number (Integer > 0)
RID	Ring identification number (see RINGAX)(Integer > 0)
HID	Harmonic identification number (Integer $\geq$ 0 or a sequence of harmonics,see note 5)
S	Scale factor (Real)
MR, MP, MZ	Moment components in the r, ϕ, z directions (Real)

Remarks:
1. This card is allowed if and only if an AXIC card is also present.
2. Load sets must be selected in the Case Control Deck (LØAD=SID) to be used by NASTRAN.
3. A separate card is needed for the definition of the moment associated with each harmonic.
4. For a discussion of the conical shell problem, see Section 5.9 of the Theoretical Manual.
5. If a sequence of harmonics is to be placed in HID the form is as follows: "Sn1Tn2" where n1 is the start of the sequence and n2 is the end of the sequence i.e., for harmonics 0 through 10, the field would contain "S0T10".

Input Data Card MØMENT Static Moment

Description: Defines a static moment at a grid point by specifying a vector.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MØMENT	SID	G	CID	M	N1	N2	N3		
MØMENT	2	5	6	2.9	0.0	1.0	0.0		

Field	Contents
SID	Load set identification number (Integer > 0)
G	Grid point identification number (Integer > 0)
CID	Coordinate system identification number (Integer ≥ 0)
M	Scale factor (Real)
N1,N2,N3	Components of Vector measured in coordinate system defined by CID (Real; $N1^2 + N2^2 + N3^2 > 0.0$)

Remarks: 1. The static moment applied to grid point G is given by

$$\vec{m} = M \cdot (N1,N2,N3)$$

2. Load sets must be selected in the Case Control Deck (LØAD=SID) to be used by NASTRAN.

3. A CID of zero references the basic coordinate system.

Input Data Card MØMENT1 Static Moment

Description: Used to define a static moment by specification of a value and two grid points which determine the direction.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MØMENT1	SID	G	M	G1	G2				
MØMENT1	6	13	-2.93	16	13				

Field	Contents
SID	Load set identification number (Integer > 0)
G	Grid point identification number (Integer > 0)
M	Value of moment (Real)
G1, G2	Grid point identification numbers (Integer > 0; G1 ≠ G2)

Remarks: 1. The direction of the moment is determined by the vector from G1 to G2.

2. Load sets must be selected in the Case Control Deck (LØAD-SID) to be used by NASTRAN.

Input Data Card MØMENT2 Static Moment

Description: Used to define a static moment by specification of a value and four grid points which determine the direction.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MØMENT2	SID	G	M	G1	G2	G3	G4		
MØMENT2	6	13	-2.93	16	13	17	13		

Field	Contents
SID	Load set identification number (Integer > 0)
G	Grid point identification number (Integer > 0)
M	Value of moment (Real)
G1,G2,G3,G4	Grid point identification numbers (Integer > 0; G1 ≠ G2; G3 ≠ G4)

Remarks: 1. The direction of the force is determined by the vector product whose factors are vectors from G1 to G2 and G3 to G4 respectively.

2. Load sets must be selected in the Case Control Deck (LØAD=SID) to be used by NASTRAN.

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Input Data Card MPC Multipoint Constraint

Description: Defines a multipoint constraint equation of the form

$$\sum_j A_j u_j = 0$$

Format and Example:

1	2	3	4	5	6	7	8	9	10
MPC	SID	G	C	A	G	C	A		abc
MPC	3	28	3	6.2	2		4.29		+B
+bc		G	C	A	-etc.-				
+B		1	4	-2.91					

Field	Contents
SID	Set identification number (Integer > 0)
G	Identification number of grid or scalar point (Integer > 0)
C	Component number - any one of the digits 1-6 in the case of geometric grid points; blank or zero in the case of scalar points (Integer)
A	Coefficient (Real; the first A must be nonzero)

Remarks:
1. The first coordinate in the sequence is assumed to be the dependent coordinate and must be unique for all equations of the set.
2. Forces of multipoint constraint are not recovered.
3. Multipoint constraint sets must be selected in the Case Control Deck (MPC=SID) to be used by NASTRAN.
4. Dependent coordinates on MPC cards may not appear on ØMIT, ØMIT1, SUPØRT, SPC or SPC1 cards; nor may the dependent coordinates be redundantly implied on ASET, ASET1, or MPCADD cards. They also may not appear as dependent coordinates in CRIGD1, CRIGD2, CRIGD3, or CRIGDR elements.

Input Data Card MPCADD Multipoint Constraint Set Definition

Description: Defines a multipoint constraint set as a union of multipoint constraint sets defined via MPC cards.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MPCADD	SID	S1	S2	S3	S4	S5	S6	S7	abc
MPCADD	100	2	3	1	6	4			
+bc	S8	S9	-etc.-						

Field	Contents
SID	Set identification number (Integer > 0; ≠ 101 or 102 if axisymmetric)
Sj	Set identification numbers of multipoint constraint sets defined via MPC cards (Integer > 0; SID ≠ Sj)

Remarks:
1. The Sj must be unique.
2. Multipoint constraint sets must be selected in the Case Control Deck (MPC=SID) to be used by NASTRAN.
3. Sj may not be the identification number of a multipoint constraint set defined by another MPCADD card.
4. Set identification numbers of 101 or 102 cannot be used in axisymmetric problems.

Input Data Card MPCAX Axisymmetric Multipoint Constraint

Description: Defines a multipoint constraint equation of the form

$$\sum_j A_j u_j = 0$$

for a model containing CCØNEAX, CTRAPAX or CTRIAAX elements.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MPCAX	SID				RID	HID	C	A	+abc
MPCAX	32				17	6	1	1.0	+1
+abc	RID	HID	C	A	RID	HID	C	A	+def
+1	23	4	2	-6.8					

-etc.-

Field	Contents
SID	Set identification number (Integer > 0; ≠ 101 or 102)
RID	Ring identification number (Integer > 0)
HID	Harmonic identification number (Integer ≥ 0)
C	Component number (1 ≤ Integer ≤ 6)
A	Coefficient (Real; the first A must be nonzero)

Remarks:
1. This card is allowed if and only if an AXIC card is also present.
2. The first coordinate in the sequence is assumed to be the dependent coordinate and must be unique for all equations of the set.
3. Multipoint constraint sets must be selected in the Case Control Deck (MPC=SID) to be used by NASTRAN.
4. Dependent coordinates appearing on MPCAX cards may not appear on ØMITAX, SPCAX, or SUPAX cards.
5. For a discussion of the conical shell problem, see Section 5.9 of the Theoretical Manual.
6. For a discussion of the axisymmetric solid problem, see Section 5.11 of the Theoretical Manual.

Input Data Card MPCS Substructure Multipoint Constraints

Description: Defines multipoint constraints within or between substructures.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MPCS	SID	NAME1	G1	C1	A1				abc
MPCS	171	WINGRT	966	1	1.0				ABC
+bc		NAME2	G21	C21	A21	G22	C22	A32	def
+BC		FUSELAGE	1036	1	.031	1036	6	32.7	DEF
+ef		NAME3	G31	C31	A31	G32	C32	A32	ghi
+EF		CABIN	39	2	.076				

Field	Contents
SID	Set identification number (Integer > 0)
NAMEi	Basic substructure name (BCD)
Gi	Grid or scalar point identification number in basic substructure NAME or NAMEi (Integer > 0)
Ci	Component number - Any one of the digits 1 - 6 in the case of geometric grid points; blank or zero in the case of scalar points (Integer > 0)
Ai	Coefficient (Real; A must be non-zero)

Remarks:

1. The first degree of freedom in the sequence is the dependent degree of freedom and must be unique for all equations of the set.

2. MPCS constraints may be imposed only at the SØLVE step of substructuring in Phase 2. Therefore, referenced grid point components must exist in the final solution substructure.

3. The operation will constrain the degrees of freedom by the equation:

$$\sum A_i u_i = 0$$

where u_i is the displacement defined by NAMEi, Gi, and Ci.

4. Components may be connected within substructures and/or to separate substructures.

5. The dependent degree of freedom may not also be referenced on any SPCS, SPCS1, SPCSD, SPC, SPC1, ØMIT, ØMIT1 or SUPØRT cards.

6. Multipoint constraint sets must be selected in the Case Control Deck (MPC=SID) to be used by NASTRAN.

7. MPCS cards may be referenced by an MPCADD card.

Input Data Card MTTPZ1 - Piezoelectric Material Temperature Dependence

Description: Specifies table references for piezoelectric material properties on a MATPZ1 card that are temperature-dependent.

Format and Example:

1	2	3	4	5	6		8	9	10
MTTPZ1	MID	R1	R2	R3	R4	R5	R6	R7	+a
MTTPZ1	703	201	202	203	204	205	206	207	+A
+a	R8	R9	R10	R11	R12	R13	R14	X	
+A	208	209	210	211	212	213	214		

Field	Contents
MID	Material property identification number which matches the identification number on some basic MATPZ1 card (Integer > 0)
Ri	References to table identification numbers for the corresponding fields on the MATPZ1 card (Integer > 0 or blank)

Remarks:

1. Blank or zero entries mean no table dependence of the referenced quantity on basic MATPZ1 card, and the quantity remains constant.
2. TABLEM1, TABLEM2, TABLEM3 and TABLEM4 type tables may be used.
3. Material properties given on the basic MATPZ1 card are initial values. If two or more quantities are to retain a fixed relationship, then two or more tables must be input to define the relationship.

Input Data Card MTTPZ2 - Piezoelectric Material Temperature Dependence

Description: Specifies table references for piezoelectric material properties on a MATPZ2 card that are temperature-dependent.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MTTPZ2	MID	R1	R2	R3	R4	R5	R6	R7	+a
MTTPZ2	35	701	702	703	704	705	706	707	+A
		⋮					⋮		
+f	R48	R49	R50	R51	X	X	X	X	
+F	748	749	750	751					

Field	Contents
MID	Material property identification number which matches the identification number on some basic MATPZ2 card (Integer > 0)
Ri	References to table identification numbers for the corresponding fields on the MATPZ2 card (Integer > 0 or blank)

Remarks:

1. Blank or zero entries mean no table dependence of the referenced quantity on the basic MATPZ2 card, and the quantity remains constant.
2. TABLEM1, TABLEM2, TABLEM3 and TABLEM4 type tables may be used.
3. Material properties given on the basic MATPZ2 card are initial values. If two or more quantities are to retain a fixed relationship, then two or more tables must be input to define the relationship.

Input Data Card NØLIN1 Nonlinear Transient Response Dynamic Load

Description: Defines nonlinear transient forcing functions of the form

$$P_i(t) = S\,T(x_j(t)) \quad ,$$

where x_j is either a displacement (u_j) or a velocity ($\dot{u}_j$).

Format and Example:

1	2	3	4	5	6	7	8	9	10
NØLIN1	SID	GI	CI	S	GJ	CJ	T		
NØLIN1	21	3	4	2.1	3	1	6		

Field	Contents
SID	Nonlinear load set identification number (Integer > 0)
GI	Grid or scalar or extra point identification number at which nonlinear load is to be applied (Integer > 0)
CI	Component number if GI is a grid point (0 < Integer ≤ 6); blank or zero if GI is a scalar or extra point
S	Scale factor (Real)
GJ	Grid or scalar or extra point identification number (Integer > 0)
CJ	Component number if GJ is a grid point (0 < Integer ≤ 6; 11 ≤ Integer ≤ 16); blank or zero or 10 if GJ is a scalar or extra point (See Remark 4 below)
T	Identification number of a TABLEDi card (Integer > 0)

Remarks:
1. Nonlinear loads must be selected in the Case Control Deck (NØNLIENAR=SID) to be used by NASTRAN.
2. Nonlinear loads may not be referenced on a DLØAD card.
3. All coordinates referenced on NØLIN1 cards must be members of the solution set. This means the u_e set for modal formulation and the $u_d = u_e + u_a$ set for direct formulation.
4. The permissible values for the component number CJ are given in the following table:

x_j \ GJ	Grid point	Scalar or extra point
Displacement (u_j)	1 ≤ Integer ≤ 6	0 or blank
Velocity ($\dot{u}_j$)	11 ≤ Integer ≤ 16	10

Note that velocity components are represented by integers ten greater than the corresponding displacement components.

(Continued)

5. If x_j is a velocity ($\dot{u}_j$), then it is determined from the relation

$$\dot{u}_{j,t} = \frac{u_{j,t} - u_{j,t-1}}{\Delta t} ,$$

where Δt is the time increment and $u_{j,t}$ and $u_{j,t-1}$ are the displacements at time t and at the previous time step respectively.

NASTRAN DATA DECK

Input Data Card <u>NØLIN2</u>   Nonlinear Transient Response Dynamic Load

<u>Description</u>: Defines nonlinear transient forcing functions of the form

$$P_i(t) = S\, x_j(t) y_k(t)$$

where x_j and y_k are either displacements (u_j, u_k) or velocities $(\dot{u}_j, \dot{u}_k)$.

<u>Format and Example</u>:

1	2	3	4	5	6	7	8	9	10
NØLIN2	SID	GI	CI	S	GJ	CJ	GK	CK	
NØLIN2	14	2	1	2.9	2	1	2	11	

<u>Field</u>	<u>Contents</u>
SID	Nonlinear load set identification number (Integer > 0)
GI	Grid or scalar or extra point identification number at which nonlinear load is to be applied (Integer > 0)
CI	Component number if GI is a grid point (0 < Integer ≤ 6); blank or zero if GI is a scalar or extra point
S	Scale factor (Real)
GJ	Grid or scalar or extra point identification number (Integer > 0)
CJ	Component number if GJ is a grid point (0 < Integer ≤ 6; 11 ≤ Integer ≤ 16); blank or zero or 10 if GJ is a scalar or extra point (See Remark 4 below)
GK	Grid or scalar or extra point identification number (Integer > 0)
CK	Component number if GK is a grid point (0 < Integer ≤ 6; 11 ≤ Integer ≤ 16); blank or zero or 10 if GK is a scalar or extra point (See Remark 4 below)

<u>Remarks</u>:

1. Nonlinear loads must be selected in the Case Control Deck (NØNLINEAR=SID) to be used by NASTRAN.
2. Nonlinear loads may <u>not</u> be referenced on a DLØAD card.
3. All coordinates referenced on NØLIN2 cards must be members of the solution set. This means the u_e set for modal formulation and the $u_d = u_e + u_a$ set for direct formulation.
4. The permissible values for the component number CJ or CK are given in the following table:

x_j or y_k \ GJ or GK	Grid point	Scalar or extra point
Displacement (u_j or u_k)	1 ≤ Integer ≤ 6	0 or blank
Velocity ($\dot{u}_j$ or $\dot{u}_k$)	11 ≤ Integer ≤ 16	10

Note that velocity components are represented by integers ten greater than the corresponding displacement components.

(Continued)

NØLIN2 (Cont.)

5. If x_j or y_k is a velocity ($\dot{u}_j$ or $\dot{u}_k$), then it is determined from the relation

$$\dot{u}_{j,t} = \frac{u_{j,t} - u_{j,t-1}}{\Delta t} \quad \text{or} \quad \dot{u}_{k,t} = \frac{u_{k,t} - u_{k,t-1}}{\Delta t}$$

   where Δt is the time increment, $u_{j,t}$ and $u_{k,t}$ are the displacements at the time t and $u_{j,t-1}$ and $u_{k,t-1}$ are the displacements at the previous time step.

6. x_j and y_k need not both represent displacements or velocities. One of them may be a displacement and the other may be a velocity.

Input Data Card NØLIN3 Nonlinear Transient Response Dynamic Load

Description: Defines nonlinear transient forcing functions of the form

$$P_i(t) = \begin{cases} S(x_j(t))^A, & x_j(t) > 0 \\ 0 \quad , & x_j(t) \leq 0 , \end{cases}$$

where x_j is either a displacement (u_j) or a velocity ($\dot{u}_j$).

Format and Example:

1	2	3	4	5	6	7	8	9	10
NØLIN3	SID	GI	CI	S	GJ	CJ	A	X	
NØLIN3	4	102		-6.1	2	5	-3.5		

Field	Contents
SID	Nonlinear load set identification number (Integer > 0)
GI	Grid or scalar or extra point identification number at which nonlinear load is to be applied (Integer > 0)
CI	Component number if GI is a grid point (0 < Integer ≤ 6); blank or zero if GI is a scalar or extra point
S	Scale factor (Real)
GJ	Grid or scalar or extra point identification number (Integer > 0)
CJ	Component number if GJ is a grid point (0 < Integer ≤ 6; 11 ≤ Integer ≤ 16); blank or zero or 10 if GJ is a scalar or extra point (See Remark 4 below)
A	Amplification factor (Real)

Remarks:

1. Nonlinear loads must be selected in the Case Control Deck (NØNLINEAR=SID) to be used by NASTRAN.
2. Nonlinear loads may not be referenced on a DLØAD card.
3. All coordinates referenced on NØLIN3 cards must be members of the solution set. This means the u_e set for modal formulation and the $u_d = u_e + u_a$ set for direct formulation.
4. The permissible values for the component number CJ are given in the following table:

x_j \ GJ	Grid point	Scalar or extra point
Displacement (u_j)	1 ≤ Integer ≤ 6	0 or blank
Velocity ($\dot{u}_j$)	11 ≤ Integer ≤ 16	10

Note that velocity components are represented by integers ten greater than the corresponding displacement components.

(Continued)

NØLIN3 (Cont.)

5. If x_j is a velocity ($\dot{u}_j$), then it is determined from the relation

$$\dot{u}_{j,t} = \frac{u_{j,t} - u_{j,t-1}}{\Delta t}$$

where Δt is the time increment and $u_{j,t}$ and $u_{j,t-1}$ are the displacements at time t and at the previous time step respectively.

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Input Data Card NØLIN4 Nonlinear Transient Response Dynamic Load

Description: Defines nonlinear transient forcing functions of the form

$$P_i(t) = \begin{cases} -S(-x_j(t))^A & , \quad x_j(t) < 0 \\ 0 & , \quad x_j(t) \geq 0 \end{cases}$$

where x_j is either a displacement (u_j) or a velocity ($\dot{u}_j$).

Format and Example:

1	2	3	4	5	6	7	8	9	10
NØLIN4	SID	GI	CI	S	GJ	CJ	A		
NØLIN4	2	4	6	2.0	101		16.3		

Field	Contents
SID	Nonlinear load set identification number (Integer > 0)
GI	Grid or scalar or extra point identification number at which nonlinear load is to be applied (Integer > 0)
CI	Component number if GI is a grid point (0 < Integer ≤ 6); blank or zero if GI is a scalar or extra point
S	Scale factor (Real)
GJ	Grid or scalar or extra point identification number (Integer > 0)
CJ	Component number if GJ is a grid point (0 < Integer ≤ 6; 11 ≤ Integer ≤ 16); blank or zero or 10 if GJ is a scalar or extra point (See Remark 4 below)
A	Amplification factor (Real)

Remarks:

1. Nonlinear loads must be selected in the Case Control Deck (NØNLINEAR=SID) to be used by NASTRAN.
2. Nonlinear loads may not be referenced on a DLØAD card.
3. All coordinates referenced on NØLIN4 cards must be members of the solution set. This means the u_e set for modal formulation and the $u_d = u_e + u_a$ set for direct formulation.
4. The permissible values for the component number CJ are given in the following table:

x_j \ GJ	Grid point	Scalar or extra point
Displacement (u_j)	1 ≤ Integer ≤ 6	0 or blank
Velocity ($\dot{u}_j$)	11 ≤ Integer ≤ 16	10

Note that velocity components are represented by integers ten greater than the corresponding displacement components.

(Continued)

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5. If x_j is a velocity ($\dot{u}_j$), then it is determined from the relation

$$\dot{u}_{j,t} = \frac{u_{j,t} - u_{j,t-1}}{\Delta t} ,$$

where Δt is the time increment and $u_{j,t}$ and $u_{j,t-1}$ are the displacements at time t and at the previous time step respectively.

Input Data Card ØMIT Omitted Coordinates

Description: Defines coordinates (degrees of freedom) that the user desires to omit from the problem through matrix partitioning. Used to reduce the number of independent degrees of freedom.

Format and Example:

1	2	3	4	5	6	7	8	9	10
ØMIT	ID	C	ID	C	ID	C	ID	C	
ØMIT	16	2	23	3516			1	4	

Field	Contents
ID	Grid or scalar point identification number (Integer > 0)
C	Component number, zero or blank for scalar points, any unique combination of the digits 1-6 for grid points

Remarks:

1. Coordinates specified on ØMIT cards may not be specified on ØMIT1, ASET, ASET1, SUPØRT, SPC or SPC1 cards nor may they appear as dependent coordinates in multipoint constraint relations (MPC) or in rigid elements (RIGD1, RIGD2, RIGD3 or RIGDR) or as permanent single-point constraints on GRID cards.

2. As many as 24 coordinates may be omitted by a single card.

3. ASET or ØMIT data are not recommended for use in heat transfer analysis with radiation effects.

Input Data Card ØMIT1 Omitted Coordinates

Description: Defines coordinates (degrees of freedom) that the user desires to omit from the problem through matrix partitioning. Used to reduce the number of independent degrees of freedom.

Format and Example:

1	2	3	4	5	6	7	8	9	10
ØMIT1	C	G	G	G	G	G	G	G	abc
ØMIT1	3	2	1	3	10	9	6	5	ABC
+bc	G	G	G	-etc.-					
+BC	7	8							

-etc.-

Alternate Form

ØMIT1	C	ID1	"THRU"	ID2					
ØMIT1	0	17	THRU	109					

Field	Contents
C	Component number (Any unique combination of the digits 1-6 (with no imbedded blanks) when point identification numbers are grid points; must be null or zero if point identification numbers are scalar points)
G,ID1,ID2	Grid or scalar point identification number (Integer > 0; ID1 < ID2)

Remarks:

1. A coordinate referenced on this card may not appear as a dependent coordinate in a multi-point constraint relation (MPC card) or as a degree of freedom on a rigid element (CRIGD1, CRIGD2, CRIGD3, CRIGDR), nor may it be referenced on a SPC, SPC1, ØMIT, ASET, ASET1, or SUPØRT card or on a GRID card as permanent single-point constraints.

2. If the alternate form is used, all of the grid (or scalar) points ID1 thru ID2 are assumed.

3. ASET or ØMIT data are not recommended for use in heat transfer analysis with radiation effects.

Input Data Card ØMITAX Axisymmetric Omitted Coordinate

Description: Defines coordinates that the user desires to omit from a model containing CCØNEAX, CTRAPAX or CTRIAAX elements through matrix partitioning. Used to reduce the number of independent degrees of freedom.

Format and Example:

1	2	3	4	5	6	7	8	9	10
ØMITAX	RID	HID	C	RID	HID	C			
ØMITAX	2	6	3	4	7	1			

Field	Contents
RID	Ring identification number (Integer > 0)
HID	Harmonic identification number (Integer ≥ 0)
C	Component number (any unique combination of the digits 1-6)

Remarks:
1. This card is allowed if and only if an AXIC card is also present.
2. Up to 12 coordinates may be omitted via this card.
3. Coordinates appearing on ØMITAX cards may not appear on MPCAX, SUPAX or SPCAX cards.
4. For a discussion of the conical shell problem, see Section 5.9 of the Theoretical Manual.
5. For a discussion of the axisymmetric solid problem, see Section 5.11 of the Theoretical Manual.

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BULK DATA DECK

Input Data Card PAERØ1 Aerodynamic Panel Property

Description: Gives associated bodies for the panels in the Doublet-Lattice method.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PAERØ1	PID	B1	B2	B3	B4	B5	B6		
PAERØ1	1	3							

Field — Contents

PID — Property identification number (referenced by CAERØ1) (Integer > 0).

B1,..., B6 — ID of associated body (Integer $\geq$ 0 or blank).

Remarks:
1. The associated body must be in the same aerodynamic group (IGID).
2. If there are no bodies, the card is still required.
3. The Bi numbers above must appear on a PAERØ2 card to define these bodies completely.

Input Data Card PAERØ2 Aerodynamic Body Properties

Description: Defines the cross-section properties of aerodynamic bodies.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PAERØ2	PID	ØRIENT	WIDTH	AR	LRSB	LRIB	LTH1	LTH2	ABC
PAERØ2	2	Z	6.0	1.0	22	91	100		abc
+BC	THI1	THN1	THI2	THN2	THI3	THN3	etc.		
+bc	1	3							

Field Contents

PID Property identification number (Integer > 0).

ØRIENT Orientation flag "Z," "Y" or "ZY." Type of motion allowed for bodies (BCD). Refers to the aerodynamic coordinate system y direction of ACSID (see AERØ data card).

WIDTH Reference half-width of body (Real > 0.).

AR Aspect ratio (height/width) (Real > 0.).

LRSB ID of an AEFACT data card containing a list of slender body half-widths. If blank, the value of WIDTH will be used (Integer ≥ 0 or blank).

LRIB ID of an AEFACT data card containing a list of interference body half-widths. If blank, the value of WIDTH will be used (Integer ≥ 0 or blank).

LTH1, LTH2 ID of AEFACT data cards for defining theta arrays for interference calculations (Integer ≥ 0 or blank).

THIi, THNi The first and last inteference element of a body to use the θ_i array (Integer ≥ 0).

Remarks:

1. The EID of all CAERØ2 elements in any IGID group must be ordered, so that their corresponding ØRIENT values appear in the order Z, ZY, Y.

2. The half-widths (given on AEFACT data cards referenced in field 6 and 7) are specified at division points. The number of entries on an AEFACT data card used to specify half-widths must be one greater than the number of elements.

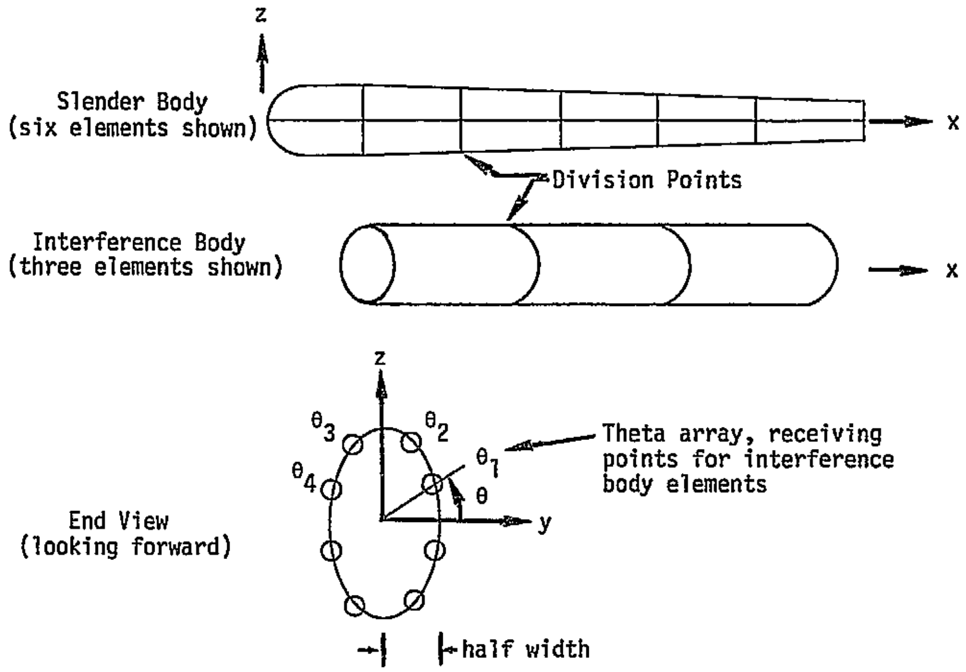
3. The half-width at the first point (i.e., the nose) on a slender body is usually 0.; thus it is recommended (but not required) that the LRSB data is supplied with a zero first entry.

4. THIi and THNi are interference element locations on a body. The first element is one for each body.

(Continued)

PAERØ2 (Cont.)

5. A body is represented by a slender body surrounded by an interference body. The slender body creates the downwash due to the motion of the body, while the interference body represents the effects upon panels and other bodies. The cross-section is elliptical.



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NASTRAN DATA DECK

Input Data Card PAERØ3 Aerodynamic Mach Box Surface Properties

Description: Defines the number of Mach boxes in the flow direction and the location of cranks and control surfaces of a Mach box lifting surface.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PAERØ3	PID	NBØX	NCTRL		X5	Y5	X6	Y6	ABC
PAERØ3	2001	15	2		0.	65.			abc
+BC	X7	Y7	X8	Y8	X9	Y9	X10	Y10	DEF
+bc	78.	65.	108.	65.	82.	97.5	112.	97.5	def
+EF	X11	Y11	X12	Y12					
+ef	86.	130.	116.	130.					

Field	Contents
PID	Property identification number (Integer > 0).
NBØX	The number of Mach boxes in flow direction (0 < Integer < 50).
NCTRL	Number of control surfaces (Integer 0, 1, or 2).
X5-Y12	Location of points 5 through 12, which are in the element coordinate system, to define the cranks and control surface geometry (Real).

Remarks:

1. The geometry is shown in a figure on the CAERØ3 Bulk Data card description.
2. If Y5 ≤ 0.0, there is no leading edge crank. Also, if Y6 ≤ 0.0, there is no trailing edge crank.
3. If NCTRL = 0, no continuation cards are needed. If NCTRL = 1 or 2, then NCTRL continuation cards are needed.
4. The relations Y7 ≥ Y8, Y9 ≥ Y10, and Y11 ≥ Y12 must hold.

Input Data Card PAERØ4 Aerodynamic Supersonic Strip Properties

Description: Gives properties of each strip element for the strip theory.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PAERØ4	PID	CLA	LCLA	CIRC	LCIRC	DØC1	CAØC1	GAPØC1	ABC
PAERØ4	6001	1	501	0	0	0.0	0.0	0.0	abc
+BC	DØC2	CAØC2	GAPØC2	DØC3	CAØC3	GAPØC3	. . . . .	etc. . .	. .
+bc	0.50	0.25	0.02	0.53	0.24	0.0			

Field	Contents
PID	Property identification number (Integer > 0).
CLA	Parameter to select Prandtl-Glauert correction (Integer -1, 0, 1, or blank). -1 - compressibility correction made to lift curve slope data for a reference Mach number. 0 or blank - no correction and no list needed. +1 - no correction and lift curve slope provided by a list as a function of strip location and Mach number.
LCLA	ID number of AEFACT data card which lists the lift curve slope on all strips for each Mach number on MKAERØi data card (Integer = 0 if CLA = 0, > 0 if CLA ≠ 0) (see Remark 7(b) below).
CIRC	Parameter to select Theodorsen's function, C(k), or the number of exponential coefficients used to approximate C(k) (Integer 0, 1, 2, 3, or blank. Must be zero if CLA ≠ 0). 0 or blank - Theodorsen function. 1,2,3 - approximate function with b_0, b_1, β_1, ... b_n, β_n) n = 1,2,3.
LCIRC	ID number of AEFACT data card which lists the b, β values for each Mach number on the MKAERØi data card (Integer = 0 if CIRC = 0, > 0 if CIRC ≠ 0) (see Remarks 7(c), 7(d), and 7(e) below; variable b's and β's for each m).
DØCi	d/c = distance of control surface hinge aft of quarter-chord divided by the strip chord (Real ≥ 0.0).
CAØCi	c_a/c = control surface chord divided by the strip chord (Real ≥ 0.0).
GAPØCi	g/c = control surface gap divided by the strip chord (Real ≥ 0.0).

Remarks:

1. This card is required for strip theory with three entries (DØCi, CAØCi, GAPØCi) per strip.
2. If CLA = -1, lift curve slope data at one Mach number are needed on the AEFACT data card.
3. If CAØCi = 0.0, there is no control surface.
4. If GAPØCi = 0.0, there is slot flow.
5. If GAPØCi < 0.01, then 0.01 is used.

(Continued)

6. Imbedded blank fields are not allowed.

7. The following table lists the lift curve slope or lag function selection and the AEFACT data card formats used for strip theory.

Theodorsen Function	Data Type Input	Parameter Combinations				Number of Words	Card Format Index
		CLA	LCLA	CIRC	LCIRC		
Exact	Lift Curve Slope $c_{\ell_{\alpha i}}=2\pi$	0	0	0	0	No AEFACT card required	
	$c_{\ell_{\alpha i}}$ input, uses Prandtl-Glauert Corr.	-1	ID	0	0	(NSTRIP+1)	(a)
	$c_{\ell_{\alpha i}}$ input, for all m's on MKAERØ card	1	ID	0	0	(NSTRIP+1)*NMACH	(b)
Approximate	Coefficients - $b_{0i}, b_{1i}, \beta_{1i}$, etc.	0	0	1	ID	4*NMACH	(c)
		0	0	2	ID	6*NMACH	(d)
		0	0	3	ID	8*NMACH	(e)

Card Format

(a) AEFACT, ID, m_1, $c_{\ell_{\alpha_1}}$, $c_{\ell_{\alpha_2}}$, ..., $c_{\ell_{\alpha_{NSTRIP}}}$

(b) AEFACT, ID, m_1, $c_{\ell_{\alpha_{11}}}$, $c_{\ell_{\alpha_{21}}}$, ..., $c_{\ell_{\alpha_{NSTRIP1}}}$, m_2, $c_{\ell_{\alpha_{12}}}$, $c_{\ell_{\alpha_{22}}}$, ..., $c_{\ell_{\alpha_{NSTRIP2}}}$,

etc., for all m on MKAERØi data card.

(c) AEFACT, ID, m_1, b_{01}, b_{11}, β_{11}, m_2, b_{02}, b_{12}, β_{12}, m_3, etc.

(d) AEFACT, ID, m_1, b_{01}, b_{11}, β_{11}, b_{21}, β_{21}, m_2, etc.

(e) AEFACT, ID, m_1, b_{01}, b_{11}, β_{11}, b_{21}, β_{21}, b_{31}, β_{31}, m_2, etc.

Input Data Card PAERØ5 Aerodynamic Strip Element Properties

Description: Gives properties of each strip element for Piston Theory.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PAERØ5	PID	NALPHA	LALPHA	NXIS	LXIS	NTAUS	LTAUS		ABC
PAERØ5	7001	1	702	1	701	1	700		abc
+BC	CAØC1	CAØC2	CAØC3	CAØC4	CAØC5	etc. . .	. . . .	. . . .	
+bc	0.0	0.0	5.25	3.99375	0.0				

Field Contents

PID Property identification number (Integer > 0).

NALPHA Number of angles of attack (α) input per Mach number (m, of MKAERØi data card) (Integer > 0) (see Remark 3 below).

LALPHA ID number of the required AEFACT data card which lists the α's (Integer > 0).

NXIS Number of dimensionless chordwise coordinates (ξ) used to define the geometry of the strips (Integer $\geq$ 0 or blank) (see Remark 4 below).

LXIS ID number of the AEFACT data card which lists the ξ's (Integer = 0 if Ca = 0, NTHICK > 0, Integer > 0 if Ca > 0, NTHICK = 0) where Ca is control surface chord length.

NTAUS Number of thickness ratios (τ) used to define the geometry of the strips (Integer $\geq$ 0 or blank).

LTAUS ID number of the AEFACT data card which lists the τ's (Integer = 0 or blank if NTAUS = 0, Integer > 0 if NTAUS > 0).

CAØCi Ratio of chord of control surface to chord of strip (Ca/c) for each strip (Real $\geq$ 0).

Remarks:

1. A PAERØ5 card is used for piston theory strip property definition and is referenced in the PID column of a CAERØ5 card.

2. The continuation card is required. The number of entries must equal the number of strips (from CAERØ5). Imbedded blank fields are forbidden, so use 0.0 if there is no control surface.

3. The following table lists the formats of the AEFACT data cards for angle of attack distribution.

TYPE OF DATA	NALPHA	LALPHA FORMAT
Same α for all strips	1	(a)
Variable α	NSTRIP	(b)

(Continued)

PAERØ5 (Cont.)

Format	Number of Words	
(a)	2*NMACH	AEFACT, ID, m_1, α_1, m_2, α_2, ...
(b)	(1+NSTRIP) *NMACH	AEFACT, ID, m_1, α_{11}, α_{21}, ..., $\alpha_{NSTRIP,1}$, ... (repeat for all m's)

4. The following table lists the formats of the AEFACT data cards for thickness and other list data.

TYPE OF INPUT DATA	CAØCi	NTHICK FORMAT	NXIS	LXIS FORMAT	NTAUS	LTAUS FORMAT
Integrals are input						
Same for all strips, no control surfaces	0.	(c)	0	0	0	0
Same for all strips with control surfaces	≠0.	(d)	1	(e)	0	0
Separate hinge for each strip with control surfaces	≠0.	(d)	NSTRIP	(f)	0	0
Thickness data are input						
Same for all strips, no control surfaces	0.	0	1	(g)	1	(h)
Same for all strips with control surfaces	≠0.	0	1	(g)	1	(h)
Separate data for each strip with control surfaces	≠0.	0	NSTRIP	(i)	NSTRIP	(j)

Format	Number of Words	
(c)	6	AEFACT, ID, I_1, I_2, I_3, I_4, I_5, I_6
(d)	12	AEFACT, ID, I_1, ..., I_6, J_1, ..., J_6
(e)	1	AEFACT, ID, ξ_h
(f)	NSTRIP	AEFACT, ID, ξ_{h1}, ξ_{h2}, ..., $\xi_{h_{NSTRIP}}$
(g)	2	AEFACT, ID, ξ_m, ξ_h
(h)	3	AEFACT, ID, τ_m, τ_h, τ_t

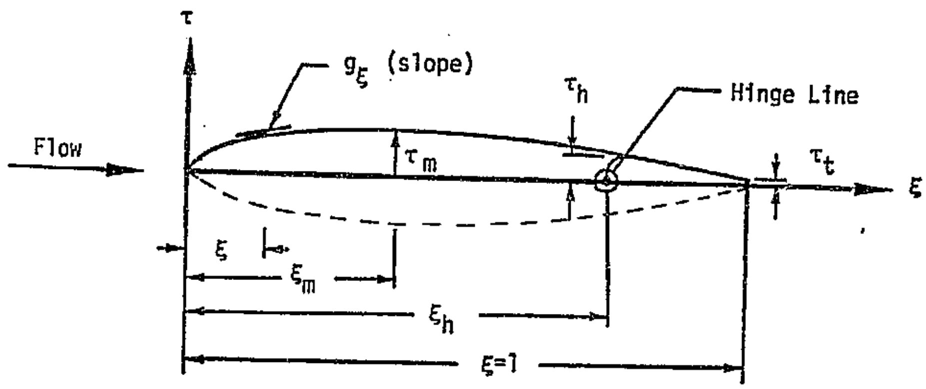
(Continued)

PAERØ5 (Cont.)

Format	Number of Words	
(i)	2*NSTRIP	AEFACT, ID, ξ_{m1}, ξ_{h1}, ..., $\xi_{h_{NSTRIP}}$
(j)	3*NSTRIP	AEFACT, ID, τ_{m1}, τ_{h1}, τ_{t1}, ..., $\tau_{t_{NSTRIP}}$

Note: If there is no hinge, you may put $\xi_h = \tau_h = 0$.

Dimensions of symmetrical airfoil, internal integral calculation:



Input Data Card PARAM Parameter

Description: Specifies values for parameters used in DMAP sequences (including rigid formats).

Format and Example :

1	2	3	4	5	6	7	8	9	10
PARAM	N	V1	V2						
PARAM	IRES	1							

Field | Contents

N Parameter name (one to eight alphanumeric characters, the first of which is alphabetic)

V1, V2 Parameter value based on parameter type as follows:

Type	V1	V2
Integer	Integer	Blank
Real, single-precision	Real	Blank
BCD	BCD	Blank
Real, double-precision	Double-precision	Blank
Complex, single-precision	Real	Real
Complex, double-precision	Double-precision	Double-precision

Remarks: 1. Only parameters for which assigned values are allowed may be given values via the PARAM card. Section 5 describes parameters as used in DMAP.

2. The following is a list of the parameters:

a. GRDPNT - optional in all DISPLACEMENT and AERØ rigid formats. A positive integer value of this parameter will cause the Grid Point Weight Generator to be executed. The value of the integer indicates the grid point to be used as a reference point. If the integer is zero (blank is not equivalent) or is not a defined grid point, the reference point is taken as the origin of the basic coordinate system. All fluid related masses are ignored. Additional details for the Grid Point Weight Generator are given in Section 5.5 of the Theoretical Manual. The following weight and balance information is automatically printed following the execution of the Grid Point Weight Generator.

(1) Reference point.

(2) Rigid body mass matrix [MØ] relative to the reference point in the basic coordinate system.

(3) Transformation matrix [S] from basic coordinate system to principal mass axes.

(4) Principal masses (mass) and associated centers of gravity (X-C.G.,Y-C.G., Z-C.G.).

(5) Inertia matrix I(S) about the center of gravity relative to the principal mass axes.

(6) Inertia matrix I(Q) about the center of gravity relative to the principal inertia axes.

(7) Transformation matrix [Q] between S-axes and Q-axes.

(Continued)

PARAM (Cont.)

b. WTMASS - optional in all DISPLACEMENT and AERØ rigid formats. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in EMA. Not recommended for use in hydroelastic problems.

c. IRES - optional in all DISPLACEMENT and HEAT statics problems (rigid formats 1, 2, 4, 5 and 6). A positive integer value of this parameter will cause the printing of the residual vectors following each execution of SSG3.

d. LFREQ and HFREQ - required in all modal formulations of DISPLACEMENT and AERØ dynamics problems (rigid formats 10, 11 and 12) unless LMØDES is used. The real values of these parameters give the cyclic frequency range (LFREQ is lower limit and HFREQ is upper limit) of the modes to be used in the modal formulation.

e. LMØDES - required in all modal formulations of DISPLACEMENT and AERØ dynamics problems (rigid formats 10, 11 and 12) unless LFREQ and HRFEQ are used. The integer value of this parameter is the number of lowest modes to be used in the modal formulation.

f. G - optional in the direct formulation of all DISPLACEMENT dynamics problems (rigid formats 7, 8 and 9). The real value of this parameter is used as a uniform structural damping coefficient in the direct formulation of dynamics problems (See Section 9.3.3 of the Theoretical Manual). Not recommended for use in hydroelastic problems.

g. W3 and W4 - optional in the direct formulation of DISPLACEMENT transient response problems (rigid format 9). The real values (radians/unit time) of these parameters are used as pivotal frequencies for uniform structural damping and element structural damping, respectively (See Section 9.3.3 of the Theoretical Manual). The parameter W3 should not be used for hydroelastic problems.

h. MØDACC - optional in the modal formulation of frequency response (rigid format 11) and transient response (rigid format 12) problems. A positive integer value of this parameter causes the Dynamic Data Recovery module to use the mode acceleration method. Not recommended for use in hydroelastic problems.

i. CØUPMASS - optional in all DISPLACEMENT and AERØ rigid formats. A positive integer value of this parameter will cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness. This option applies to both structural and nonstructual mass for the following elements: BAR, CØNRØD, QUAD1, QUAD2, RØD, TRIA1, TRIA2, TUBE. Since structural mass is not defined for the following list of elements, the option applies only to the nonstructural mass: QDPLT, TRBSC, TRPLT. A negative value causes the generation of lumped mass matrices (translational components only) for all the above elements. (This is the default). A zero value activates the following parameters described under j.

j. CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional in all DISPLACEMENT and AERØ rigid formats. These parameters are active only if CØUPMASS=0. A positive value will cause the generation of coupled mass matrices for all elements of that particular type as shown by the following table:

Parameter	Element Types
CPBAR	BAR
CPRØD	RØD, CONRØD
CPQUAD1	QUAD1
CPQUAD2	QUAD2
CPTRIA1	TRIA1
CPTRIA2	TRIA2
CPTUBE	TUBE
CPQDPLT	QDPLT
CPTRPLT	TRPLT
CPTRBSC	TRBSC

A negative value (the default) for these parameters will cause the generation of the lumped mass matrices (translational components only) for these element types.

(Continued)

PARAM (Cont.)

k. MAXIT - optional in nonlinear static HEAT transfer analysis (rigid format 3). The integer value of this parameter limits the maximum number of iterations. The default value is 4 iterations.

l. EPSHT - optional in nonlinear static HEAT transfer analysis (rigid format 3). The real value of this parameter is used to test the convergence of the nonlinear heat transfer solution (see Section 8.4.1 of the Theoretical Manual). The default value is .001.

m. TABS - optional in nonlinear static (rigid format 3) and transient (rigid format 9) HEAT transfer analysis. The real value of this parameter is the absolute reference temperature. The default value is 0.0.

n. SIGMA - optional in nonlinear static (rigid format 3) and transient (rigid format 9) HEAT transfer analysis. The real value of this parameter is the Stefan-Boltzman constant. The default value is 0.0.

o. BETA - optional in transient HEAT transfer analysis (rigid format 9). The real value of this parameter is used as a factor in the integration algorithm (see Section 8.4.2 of the Theoretical Manual). The default value is 0.55.

p. RADLIN - optional in transient HEAT transfer analysis (rigid format 9). A positive integer value of this parameter causes some of the radiation effects to be linearized (see Equation 2, Section 8.4.2 of the Theoretical Manual). The default value is -1.

q. BETAD - optional in static analysis with differential stiffness (rigid format 4). The integer value of this parameter is the number of iterations allowed for computing the load correction in the inner (load) loop before shifting to the outer (stiffness) loop which adjusts the differential stiffness. The default value is 4 iterations.

r. NT - optional in static analysis with differential stiffness (rigid format 4). The integer value of this parameter limits the cumulative number of iterations in both loops. The default value is 10 iterations.

s. EPSIØ - optional in static analysis with differential stiffness (rigid format 4). The real value of this parameter is used to test the convergence of iterated differential stiffness. The default value is 10^{-5}.

t. CTYPE - required in cyclic symmetry analysis (rigid formats 14 and 15). The BCD value of this parameter defines the type of cyclic symmetry as follows:

(1) RØT - rotational symmetry
(2) DRL - dihedral symmetry, using right and left halves
(3) DSA - dihedral symmetry, using symmetric and antisymmetric components.

u. NSEGS - required in cyclic symmetry analysis (rigid formats 14 and 15). The integer value of this parameter is the number of identical segments in the structural model.

v. NLØAD - optional in static analysis with cyclic symmetry (rigid format 14). The integer value of this parameter is the number of static loading conditions. The default value is 1.

w. CYCIØ - optional in static analysis with cyclic symmetry (rigid format 14). The integer value of this parameter specifies the form of the input and output data. A value of +1 is used to specify physical segment representation, and a value of -1 for cyclic transform representation. The default value is +1.

x. CYCSEQ - optional in cyclic symmetry analysis (rigid formats 14 and 15). The integer value of this parameter specifies the procedure for sequencing the equations in the solution set. A value of +1 specifies that all cosine terms should be sequenced before all sine terms, and a value of -1 for alternating the cosine and sine terms. The default value is -1.

(Continued)

y. KMAX - optional in static analysis with cyclic symmetry (rigid format 14). The integer value of this parameter specifies the maximum value of the harmonic index. The default value is ALL which is NSEGS/2 for NSEGS even and (NSEGS-1)/2 for NSEGS odd.

z. KINDEX - required in normal modes with cyclic symmetry (rigid format 15). The integer value of this parameter specifies a single value of the harmonic index.

aa. NØDJE - optional in AERØ rigid formats. A positive integer of this parameter indicates user supplied downwash matrices due to extra points are to be read from tape via the INPUTT2 module in the rigid format. The default value is -1.

ab. P1, P2, and P3 - required in AERØ rigid formats when using NØDJE parameter. See Section 5.5 for tape operation parameters required by INPUTT2 module. The defaults for P1, P2, and P3 are 0,11, and XXXXXXXX, respectively.

ac. VREF - optional in modal flutter analysis (rigid format 10). Velocities are divided by the real value of this parameter to convert units or to compute flutter indices. The default value is 1.0.

ad. PRINT - optional in modal flutter analysis (rigid format 10). The BCD value, NØ, of this parameter will suppress the automatic printing of the flutter summary for the K method. The default value is YES.

ae. ISTART - optional in direct and modal transient response (rigid formats 9 and 12). A positive value of this parameter will cause the second (or alternate) starting method to be used (see Section 11.3 of the Theoretical Manual). The alternate starting method is recommended when initial accelerations are significant and when the mass matrix is non-singular. The default value is -1 and will cause the first starting method to be used.

af. KDAMP - optional in AERØ rigid formats. An integer value of +1 causes modal damping terms to be put into the complex stiffness matrix for structural damping. The default is -1.

ag. GUSTAERØ - optional in AERØ rigid formats. An integer value of +1 causes gust loads to be computed. The default is -1.

ah. IFTM - optional in aeroelastic response (rigid format 11). The value of this parameter selects the method for the integration of the Inverse Fourier Transform. The integer value 0 specifies a rectangular fit; 1 specifies a trapezoidal fit; and 2 specifies a cubic spline fit to obtain solutions versus time for which aerodynamic forces are functions of frequency. The default value is 0.

ai. MACH - optional in AERØ rigid formats. The real value of this parameter selects the closest Mach numbers to be used to compute aerodynamic matrices. The default is 0.0.

aj. Q - required in aeroelastic response (rigid format 11). The real value of this parameter defines the dynamic pressure.

ak. ØPT - optional in static and normal modes analyses (rigid formats 1, 2, 3, 14, and 15). A positive integer value of this parameter causes both equilibrium and multipoint constraint forces to be calculated for the Case Control output request, MPCFØRCE. A negative integer value of this parameter causes only the equilibrium force balance to be calculated for the output request. The default value is 0 which causes only the multipoint constraint forces to be calculated for the output request.

aℓ. GRDEQ - optional in static and normal modes analyses (rigid formats 1, 2, 3, 14, and 15). A positive integer value of this parameter selects the grid point about which equilibrium will be checked for the Case Control output request, MPCFØRCE. If the integer value is zero, the basic origin is used. Default is -1.

(Continued)

am. STRESS - optional in static analysis (rigid format 1). This parameter controls the transformation of element stresses to the material coordinate system (only for TRIA1, TRIA2, QUAD1 and QUAD2 elements). If it is a positive integer, the stresses for these elements are transformed to the material coordinate system. If it is zero, stresses at the connected grid points are also computed in addition to the element stresses in the material coordinate system. A negative integer value results in no transformation of the stresses. The default value is -1.

an. STRAIN - optional in static analysis (rigid format 1). This parameter controls the transformation of element strains/curvatures to the material coordinate system (only for TRIA1, TRIA2, QUAD1 and QUAD2 elements). If it is a positive integer, the strains/curvatures for these elements are transformed to the material coordinate system. If it is zero, strains/curvatures at the connected grid points are also computed in addition to the element strains/curvatures in the material coordinate system. A negative integer value results in no transformation of the strains/curvatures. The default value is -1.

ao. NINTPTS - optional in static analysis (rigid format 1). A positive integer value of this parameter specifies the number of closest independent points to be used in the interpolation for computing stresses or strains/curvatures at grid points (only for TRIA1, TRIA2, QUAD1 and QUAD2 elements). A negative integer value or 0 specifies that all independent points are to be used in the interpolation. The default value is 0.

Input Data Card PBAR Simple Beam Property

Description: Defines the properties of a simple beam (bar) which is used to create bar elements via the CBAR card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PBAR	PID	MID	A	I1	I2	J	NSM		abc
PBAR	39	6	2.9		5.97				123
+bc	C1	C2	D1	D2	E1	E2	F1	F2	def
+23			2.0	4.0					
+ef	K1	K2	I12						

Field	Contents
PID	Property identification number (Integer > 0)
MID	Material identification number (Integer > 0)
A	Area of bar cross-section (Real)
I1, I2, I12	Area moments of inertia (Real, $I_1 I_2 \geq I_{12}^2$)
J	Torsional constant (Real)
NSM	Nonstructural mass per unit length (Real)
K1, K2	Area factor for shear (Real)
Ci, Di, Ei, Fi	Stress recovery coefficients (Real)

Remarks:

1. For structural problems, PBAR cards may only reference MAT1 material cards.
2. See Section 1.3.2 for a discussion of bar element geometry.
3. For heat transfer problems, PBAR cards may only reference MAT4 or MAT5 material cards.
4. The quantities, K1 and K2, are expressed as the relative amounts (0.0 to 1.0) of the total cross-sectional area contributing to the transverse shear stiffnesses (KAG) in the direction of the two principal axes. These quantities are ignored if I12 is non-zero.

Input Data Card PCØNEAX Conical Shell Element Property

Description: Defines the properties of a conical shell element described on a CCØNEAX card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PCØNEAX	ID	MID1	T1	MID2	I	MID3	T2	NSM	+abc
PCØNEAX	2	4	1.0	6	16.3	8	2.1	0.5	+1
+abc	Z1	Z2	PHI1	PHI2	PHI3	PHI4	PHI5	PHI6	+def
+1	0.001	-0.002	23.6	42.9					+2
+def	PHI7	PHI8	PHI9	PHI10	PHI11	PHI12	PHI13	PHI14	
+2									

Field	Contents
ID	Property identification number (Unique Integer > 0)
MIDi	Material identification number for membrane, bending, and transverse shear (Integer $\geq$ 0)
T1,T2	Membrane thickness and transverse shear thickness (Real > 0.0 if MIDi $\neq$ 0)
I	Moment of Inertia per unit width (Real)
NSM	Nonstructural mass per unit area (Real)
Z1, Z2	Fiber distances for stress recovery (Real)
PHIi	Azimuthal coordinates (in degrees) for stress recovery (Real)

Remarks:

1. This card is allowed if and only if a AXIC card is also present.
2. PCØNEAX cards may only reference MAT1 material cards.
3. If either MID1 = 0 or blank or T1 = 0.0 or blank, then both must be zero or blank.
4. If either MID2 = 0 or blank or I = 0.0 or blank, then both must be zero or blank.
5. If either MID3 = 0 or blank or T2 = 0.0 or blank, then both must be zero or blank.
6. A maximum of 14 azimuthal coordinates for stress recovery may be specified. An error will be detected if more than two (2) continuation cards appear.
7. For a discussion of the conical shell problem, see Section 5.9 of the Theoretical Manual.

Input Data Card PDAMP Scalar Damper Property

Description: Used to define the damping value of a scalar damper element which is defined by means of the CDAMP1 or CDAMP3 cards.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PDAMP	PID	B	PID	B	PID	B	PID	B	
PDAMP	14	-2.3	2	6.1					

Field	Contents
PID	Property identification number (Integer > 0)
B	Value of scalar damper (Real)

Remarks:
1. This card defines a damper value. The user is cautioned to be careful when using negative damper values. Damper values are defined directly on the CDAMP2 and CDAMP4 cards. A structural viscous damper, CVISC, may also be used for geometric grid points.

2. Up to four damper properties may be defined on a single card.

3. For a discussion of scalar elements, see Section 5.6 of the Theoretical Manual.

Input Data Card PDUMi   Dummy Element Property

Description: Defines the properties of a dummy element ($1 \leq i \leq 9$). Referenced by the CDUMi card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PDUMi	PID	MID	A1	A2			-etc.-		abc
PDUM3	108	2	2.4	9.6	1.E4	15.		3.5	ABC
+bc		-etc.-	AN						
+BC	5		2						

Field	Contents
PID	Property identification number (Integer > 0)
MID	Material identification number (Integer > 0)
A1...AN	Additional entries (Real or Integer)

Remarks: The additional entries are defined in the user written element routines.

Input Data Card PELAS   Scalar Elastic Property

Description: Used to define the stiffness, damping coefficient, and stress coefficient of a scalar elastic element (spring) by means of the CELAS1 or CELAS3 card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PELAS	PID	K	GE	S	PID	K	GE	S	
PELAS	7	4.29	0.06	7.92	27	2.17	0.0032		

Field	Contents
PID	Property identification number (Integer > 0)
K	Elastic property value (Real)
GE	Damping coefficient, g_e (Real)
S	Stress coefficient (Real)

Remarks:

1. The user is cautioned to be careful using negative spring values. (Values are defined directly on some of the CELASi card types.)
2. One or two elastic spring properties may be defined on a single card.
3. For a discussion of scalar elements, see Section 5.6 of the Theoretical Manual.

Input Data Card PELBØW - Curved Beam or Elbow Property

Description: Defines the properties of a curved beam or elbow element which is used to create curved pipe or beam elements via the CELBØW card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PELBØW	PID	MID	A	I1	I2	J	NSM		+abc
PELBØW	2	6061	16.0	211.0	211.0	422.0	6.0		+P1

+abc	r_1	θ_1	r_2	θ_2	r_3	θ_3	r_4	θ_4	+def
+P1	5.3	0.0	5.3	90.0	5.3	180.0	5.3	270.0	+P2

+def	K1	K2	C	K_x	K_y	K_z	R	β	
+P2	2.0	2.0	1.0	1.0	5.76	5.76	15.0	90.0	

Field	Contents
PID	Property identification number (Integer > 0)
MID	Material identification number (Integer > 0)
A	Area of cross section (Real > 0.0)
I1	Area moment of inertia in Plane 1 (Real)
I2	Area moment of inertia in Plane 2 (Real)
J	Torsional constant (Real)
NSM	Nonstructural mass per unit length (Real)
r_i, θ_i	Stress recovery coefficients (Real, θ in degrees) (See Figure 2 below)
K1,K2	Area factors for shear (Real)
C	Stress intensification factor (Real)
K_x, K_y, K_z	Flexibility correction factors (Real)
R	Radius of curvature of the element (Real > 0.0)
β	Angle, in degrees, from GA to GB (Real, $0. < \beta < 180.$) (See Figure 1 below)

(Continued)

<u>PELBØW</u> (Cont.)

<u>Remarks</u>:

1. For structural problems, PELBØW may only reference MAT1 cards.
2. For APP HEAT problems, PELBØW cards may only reference MAT4 or MAT5 material cards.
3. The product moment of inertia is zero (I12 = 0). This assumes that at least one axis of symmetry of the element cross section exists, e.g., tube, I-beam, channel, tee, etc.
4. See Section 1.3.2.2 for a discussion of the stress correction factor and the flexibility correction factors.

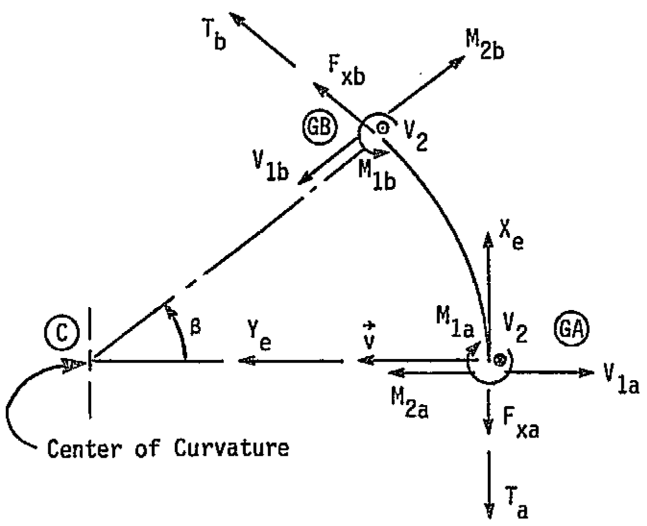


Figure 1. Element local coordinate system

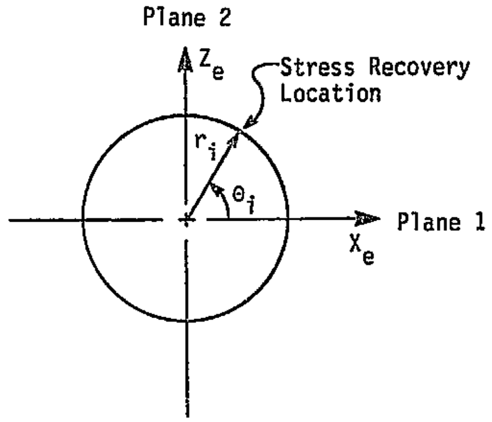


Figure 2. Element cross-section

Input Data Card PERMBDY - Permeability Boundary

Description: Specifies grid points on boundaries of dissimilar magnetic permeability.

Format and Format:

1	2	3	4	5	6	7	8	9	10
PERMBDY	G1	G2	G3	G4	G5	G6	G7	G8	+a
PERMBDY	1	5	7	8	10	12	20	25	+A

+a	G9	G10	G11	G12	G13	G14	G15	G16	+b
+A	30	40	ENDT						

Field	Contents
Gi	Grid point identification numbers (Integers > 0)

Remarks:

1. There may be only one PERMBDY card.
2. The grid points on PERMBDY are those points which are on boundaries between elements of differing magnetic permeability.
3. The PERMBDY card is not required, but its use is recommended. See Section 1.15.4.4 for more details.

Input Data Card PHBDY   Property of Heat Boundary Element

Description: Defines the properties of the HBDY element.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PHBDY	PID	MID	AF	E	ALPHA	R1	R2		
PHBDY	100	103	300.	.79					

Field	Contents
PID	Property identification number (Integer > 0)
MID	Material identification number (Integer ≥ 0 or blank), used for convective film coefficient and thermal capacity.
AF	Area factor (Real ≥ 0.0 or blank). Used only for HBDY types PØINT, LINE, and ELCYL.
E	Emissivity (0.0 ≤ Real ≤ 1.0 or blank). Used only for radiation calculations.
ALPHA	Absorbtivity (0.0 < Real < 1.0 or blank). Used only for thermal vector flux calculations, default value is E.
R1,R2	"Radii" of elliptic cylinder. Used for HBDY type "ELCYL". See the HBDY element description. (Real)

Remarks:

1. The referenced material Id must be on a MAT4 card. The card defines the convective film coefficient and thermal capacity per unit area. If no material is referenced the element convection and heat capacity are zero.

2. The area factor AF is used to determine the effective area. For a "PØINT", AF = area; for "LINE" or "ELCYL", AF = effective width where area = AF·length. The effective area is automatically calculated for other HBDY types.

Input Data Card PIHEX Isoparametric Hexahedron Property

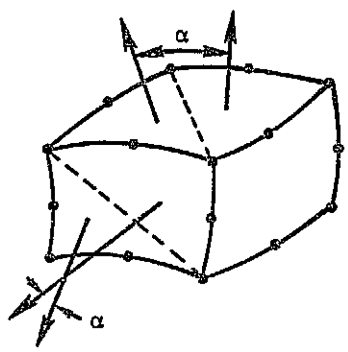
Description: Defines the properties of an isoparametric solid element, including a material reference and the number of integration points. Referenced by the CIHEX1, CIHEX2, and CIHEX3 cards.

Format and Example:

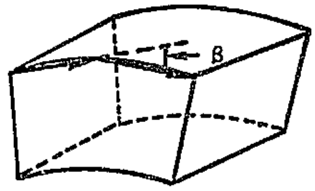
1	2	3	4	5	6	7	8	9	10
PIHEX	PID	MID	CID	NIP	AR	ALFA	BETA		
PIHEX	15	3		3			5.0		

Field	Contents
PID	Property identification number (Integer > 0)
MID	Material identification number (Integer > 0)
CID	Identification number of the coordinate system in which the material referenced by MID is defined (Integer ≥ 0 or blank)
NIP	Number of integration points along each edge of the element (Integer = 2, 3, 4 or blank)
AR	Maximum aspect ratio (ratio of longest to shortest edge) of the element (Real > 1.0 or blank)
ALFA	Maximum angle in degrees between the normals of two subtriangles comprising a quadrilateral face (Real, 0.0 ≤ ALFA ≤ 180.0, or blank)
BETA	Maximum angle in degrees between the vector connecting a corner point to an adjacent midside point and the vector connecting that midside point and the other midside or corner point (Real, 0.0 ≤ BETA ≤ 180.0, or blank)

Examples of Field Definitions:



Example of ALFA



Example of BETA

(Continued)

Remarks: 1. All PIHEX cards must have unique identification numbers.

2. CID is not used for isotropic materials.

3. The default for CID is the basic coordinate system.

4. The default for NIP is 2 for IHEX1 and 3 for IHEX 2 and IHEX3.

5. AR, ALFA, and BETA are used for checking the geometry of the element. The defaults are:

	AR	ALFA (degrees)	BETA (degrees)
CIHEX1	5.0	45.0	--
CIHEX2	10.0	45.0	45.0
CIHEX3	15.0	45.0	45.0

6. Anisotropic materials may be used by reference to a MAT6 card (with or without a MATT6 card) on the PIHEX card.

Input Data Card PIS2D8 - Quadratic Isoparametric Element Property

Description: Used to define the properties of a quadriparabolic isoparametric membrane element. Referenced by the CIS2D8 card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PIS2D8	PID	MID	T						
PIS2D8	2	1	0.5						

Field	Contents
PID	Property identification number (Integer > 0)
MID	Material identification number (Integer > 0)
T	Thickness of membrane (Real)

Remarks:
1. All PIS2D8 cards must have unique property identification members.
2. The material property identification number must reference only a MAT1 or MAT2 card.

Input Data Card PLFACT Piecewise Linear Analysis Factor Definition Card

Description: Defines scale factors for Piecewise Linear Analysis loading.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PLFACT	SID	B1	B2	B3	B4	B5	B6	B7	+abc
PLFACT	6	0.2	0.3	0.4	0.5	0.6	0.7	0.8	ABC
+abc	B8	B9	-etc.-						
+BC	0.9	1.0							

Field	Contents
SID	Unique set identification number (Integer > 0)
Bi	Loading factor (Real)

Remarks:
1. The remainder of the physical card containing the last entry must be null.
2. At any stage of the Piecewise Linear Analysis, the accumulated load is given by

$$\{P_i\} = B_i\{P\}$$

where {P} is the total load defined in the usual way.

Example: If it were desired to load the structure in ten equally spaced load increments then set

$$B_i = 0.1 \cdot i \quad ; \quad i = 1, 10$$

3. Normally, the B_i form a monotonically increasing sequence. A singular stiffness matrix will result if $B_i = B_{i-1}$.
4. At least two factors must be defined.
5. Piecewise Linear Analysis factor sets must be selected in the Case Control Deck (PLCØEFF=SID) to be used by NASTRAN.

NASTRAN DATA DECK

Input Data Card PLIMIT   Property Optimization Limits

Description: Defines the maximum and minimum limits for ratio of new property to original property.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PLIMIT	ELTYP	KMIN	KMAX	PID1	PID2	PID3	PID4	PID5	+abc
PLIMIT	RØD	.01	1.5	1	3	5	4	2	+ABC

+bc	PID6	-etc.-							
+BC		-etc.-							

Alternate form:

PLIMIT	ELTYP	KMIN	KMAX	PID1	"THRU"	PIDi			
PLIMIT	ALL	.001	0.05	30	"THRU"	36			

Field	Contents
ELTYP	One of the following element types: RØD, TUBE, BAR, TRMEM, QDMEM, TRPLT, QDPLT, TRBSC, TRIA1, QUAD1, TRIA2, QUAD2, SHEAR, or ALL or blank.
KMIN	Minimum property ratio (Real > 0.0 or blank)
KMAX	Maximum property ratio (Real > KMIN or = 0.0 or blank)
PIDn	List of property identification numbers associated with KMIN and/or KMAX (Integer > 0)

Remarks:
1. This card is not required (Default KMIN = KMAX = 0.0 for ALL elements).
2. All PID values must be unique for each element type.
3. All elements with the same property identification number in the output stress data block, ØES1, have these limits applied if ALL is specified.
4. Property entries optimized depend on the element type and material stress limits. Only nonzero properties with nonzero stress limits are optimized.
5. If KMAX = 0.0, no limit is placed on the maximum change.
6. If ELTYP is blank, ALL is assumed.
7. One of KMIN or KMAX may be blank but not both.

Input Data Card PLØAD Static Pressure Load

Description: Defines a static pressure load.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PLØAD	SID	P	G1	G2	G3	G4			
PLØAD	1	-4.0	16	32	11				

Field	Contents
SID	Load set identification number (Integer > 0)
P	Pressure (Real)
G1,G2,G3,G4	Grid point identification numbers (Integer > 0; G4 may be zero)

Remarks:

1. Grid points must be unique and noncollinear.
2. If four grid points are given, four triangles are formed and half of P is applied to each one. For each triangle the direction is defined by

$$+(\vec{r}_{12} \times \vec{r}_{13})$$

where $\vec{r}_{ij}$ is the vector from Gi to Gj.

3. Load sets must be selected in the Case Control Deck (LØAD=SID) to be used by NASTRAN.

Input Data Card PLØAD2 Pressure Load

Description: Defines a uniform static pressure load applied to two-dimensional elements. Only QUAD1, QUAD2, QDMEM, QDMEM1, QDMEM2, QDPLT, SHEAR, TRBSC, TRIA1, TRIA2, TRMEM, TRPLT or TWIST elements may have a pressure load applied to them via this card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PLØAD2	SID	P	EID	EID	EIDm	"THRU"	EIDn	EID	abc
PLØAD2	21	-3.6	1	4	16	THRU	22	98	ABC

+bc	EID	-etc.-							def
+BC	127								

-etc.-

Field	Contents
SID	Load set identification number (Integer > 0)
P	Pressure value (Real)
EID EIDm EIDn	Element identification numbers (Integer > 0; EIDm < EIDn)

Remarks:

1. EID must be 0 or blank for omitted entries.
2. Load sets must be selected in the Case Control Deck (LØAD=SID) to be used by NASTRAN.
3. At least one positive EID must be present on each PLØAD2 card.
4. The pressure load is computed for each element as if the grid points to which the element is connected were specified on a PLØAD card. The grid point sequence specified on the element connection card is assumed for the purpose of computing pressure loads.
5. All elements referenced must exist.
6. EID may be specified as individual references or as sequential lists ("THRU" sequences) and the two methods may be used interchangeably. The only restriction is that integer values must appear in fields 4 and 9 on the PLØAD2 card and in fields 2 and 9 on each continuation card (if all fields are used).

Input Data Card PLØAD3 Pressure Load on a Face of an Isoparametric Element

Description: Defines a uniform static pressure load applied to a surface of an isoparametric hexahedron element only.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PLØAD3	SID	P	EID1	G11	G12	EID2	G21	G22	
PLØAD3	3	-15.1	15	7	25	16	117	135	

Field	Contents
SID	Load set identification number (Integer > 0)
P	Pressure value (Real, force per unit area)
EID1, EID2	Element identification number (Integer > 0)
G11, G12, G21, G22	Grid point identification number of two grid points at diagonally opposite corners of the face on which the pressure acts (Integers > 0)

Remarks:

1. Load sets must be selected in the Case Control Deck (LØAD = SID) to be used by NASTRAN.
2. At least one EID must be present on each PLØAD3 card.
3. All elements referenced must exist.
4. Computations consider the pressure to act positive outward on specified face of element.

Input Data Card PLØTEL   Dummy Element Definition

Description: Defines a dummy one-dimensional element for use in plotting. This element is not used in the model during any of the solution phases of a problem. It is used to simplify plotting of structures with large numbers of collinear grid points where the plotting of each one along with the elements connecting them would result in a confusing plot. The use of this "element" is entirely the responsibility of the user.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PLØTEL	EID	G1	G2		EID	G1	G2		
PLØTEL	29	35	16						

Field	Contents
EID	Element identification number (Integer > 0)
G1, G2	Grid point identification numbers of connection points (Integer > 0; G1 ≠ G2)

Remarks: 1. Element identification numbers must be unique with respect to all other element identification numbers.

2. One or two PLØTEL elements may be defined on a single card.

Input Data Card PMASS Scalar Mass Property

Description: Used to define the mass value of a scalar mass element which is defined by means of the CMASS1 or CMASS3 cards.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PMASS	PID	M	PID	M	PID	M	PID	M	
PMASS	7	4.29	6	13.2					

Field	Contents
PID	Property identification number (Integer > 0)
M	Value of scalar mass (Real)

Remarks:

1. This card defines a mass value. The user is cautioned to be careful when using negative mass values. (Values are defined directly on some of the CMASSi card types.)
2. Up to four mass properties may be defined by this card.
3. For a discussion of scalar elements, see Section 5.6 of the Theoretical Manual.

NASTRAN DATA DECK

Input Data Card PØINTAX Axisymmetric Point

Description: Defines the location of a point on an axisymmetric ring at which loads may be applied via the FØRCE, FØRCEAX, MØMENT or MØMAX cards and at which displacements may be requested.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PØINTAX	ID	RID	PHI	X	X	X	X	X	
PØINTAX	2	3	30.0						

Field	Contents
ID	Point identification number (Unique Integer > 0)
RID	Identification number of a RINGAX card (Integer > 0)
PHI	Azimuthal angle in degrees (Real)

Remarks:
1. This card is allowed if and only if an AXIC card is also present.
2. PØINTAX identification numbers must be unique with respect to all other PØINTAX, RINGAX, and SECTAX identification numbers.
3. These points are not subject to constraints via MPCAX, SPCAX, or ØMITAX card.
4. For a discussion of the conical shell problem, see Section 5.9 of the Theoretical Manual.
5. For a discussion of the axisymmetric solid problem, see Section 5.11 of the Theoretical Manual.

Input Data Card PØPT Property Optimization Parameter

Description: Defines the basic parameters and existence of a property optimization analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PØPT	MAX	EPS	GAMA	PRINT	PUNCH				
PØPT	2	1.0E-3	0.9	2	NØ				

Field	Contents
MAX	Maximum number of iterations on property values (Integer > 0)
EPS	Convergence criteria for property value. If zero, no convergence check (Real ≥ 0.0)
GAMA	Iteration factor (Default = 1.0) (Real > 0.0)
PRINT	Print control for property parameters and ØFP. Printout occurs every Ith loop. The first and last loops are always printed (Integer > 0)
PUNCH	Property card punch option. If YES, properties that were optimized are punched (BCD, "YES" or "NO")

Remarks:
1. Only one PØPT card is allowed.
2. All subcases will be analyzed MAX+1 times unless all properties converge.
3. Property convergence is defined by

$$\frac{|\sigma-\sigma_\ell|}{\sigma_\ell} < \text{EPS}$$

where σ is the maximum stress and σ_ℓ is the appropriate stress limit on the material card.

4. Stress recovery must be requested for one of the following elements: RØD, TUBE, BAR, TRMEM, QDMEM, TRPLT, QDPLT, TRBSC, TRIA1, QUAD1, TRIA2, QUAD2, or SHEAR. In addition, the material card must have stress limits defined.
5. Property cards are always printed for the last iteration.
6. The property entry optimized depends on the element type and the material stress limits (see Section 1.13).

NASTRAN DATA DECK

Input Data Card PQDMEM   Quadrilateral Membrane Property

Description: Used to define the properties of a quadrilateral membrane. Referenced by the CQDMEM card. No bending properties are included.

Foramt and Example:

1	2	3	4	5	6	7	8	9	10
PQDMEM	PID	MID	T	NSM	PID	MID	T	NSM	
PQDMEM	235	2	0.5	0.0					

Field	Contents
PID	Property identification number (Integer > 0)
MID	Material identification number (Integer > 0)
T	Thickness of membrane (Real > 0.0)
NSM	Nonstructural mass per unit area (Real)

Remarks:
1. All PQDMEM cards must have unique property identification numbers.
2. One or two quadrilateral membrane properties may be defined on a single card.

Input Data Card PQDMEM1 Isoparametric Quadrilateral Membrane Property

Description: Used to define the properties of an isoparametric quadrilateral membrane. Referenced by the CQDMEM1 card. No bending properties are included.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PQDMEM1	PID	MID	T	NSM	PID	MID	T	NSM	
PQDMEM1	235	2	0.5	0.0					

Field	Contents
PID	Property identification number (Integer > 0)
MID	Material identification number (Integer > 0)
T	Thickness of membrane (Real > 0.0)
NSM	Nonstructural mass per unit area (Real)

Remarks:
1. All PQDMEM1 cards must have unique property identification numbers.
2. One or two isoparametric quadrilateral membrane properties may be defined on a single card.

Input Data Card PQDMEM2 Quadrilateral Membrane Property

Description: Used to define the properties of a quadrilateral membrane. Referenced by the CQDMEM2 card. No bending properties are included.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PQDMEM2	PID	MID	T	NSM	PID	MID	T	NSM	
PQDMEM2	235	2	0.5	0.0					

Field	Contents
PID	Property identification number (Integer > 0)
MID	Material identification number (Integer > 0)
T	Thickness of membrane (Real > 0.0)
NSM	Nonstructural mass per unit area (Real)

Remarks: 1. All PQDMEM2 cards must have unique property identification numbers.

2. One or two quadrilateral membrane properties may be defined on a single card.

BULK DATA DECK

Input Data Card <u>PQDPLT</u> Quadrilateral Plate Property

<u>Description:</u> Used to define the bending properties of a quadrilateral plate element. Referenced by the CQDPLT card. No membrane properties are included.

<u>Format and Example:</u>

1	2	3	4	5	6	7	8	9	10
PQDPLT	PID	MID1	I	MID2	T	NSM	Z1	Z2	
PQDPLT	16	23	4.29	16	2.63	1.982	0.05	-0.05	

Field	Contents
PID	Property identification number (Integer > 0)
MID1	Material identification number for bending (Integer > 0)
I	Bending area moment of inertia per unit width (Real)
MID2	Material identification number for transverse shear (Integer ≥ 0)
T	Transverse shear thickness (Real)
NSM	Nonstructural mass per unit area (Real)
Z1, Z2	Fiber distances for stress computation, positive according to the right-hand sequences defined on the CQDPLT card (Real)

<u>Remarks:</u> 1. All PQDPLT cards must have unique property identification numbers.

2. If T is zero, the element is assumed to be rigid in transverse shear.

3. No structural mass is generated for this element.

NASTRAN DATA DECK

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Input Data Card PQUAD1 General Quadrilateral Element Property

Description: Defines the properties of a general quadrilateral element of the structural model, including bending, membrane, and transverse shear effects. Referenced by the CQUAD1 card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PQUAD1	PID	MID1	T1	MID2	I	MID3	T3	NSM	abc
PQUAD1	32	16	2.98	9	6.45	16	5.29	6.32	WXYZ1
+bc	Z1	Z2							
+XYZ1	0.09	-0.06							

Field	Contents
PID	Property identification number (Integer > 0)
MID1	Material identification number for membrane (Integer $\geq$ 0)
T1	Membrane thickness (Real)
MID2	Material identification number for bending (Integer $\geq$ 0)
I	Area moment of inertia per unit width (Real)
MID3	Material identification number for transverse shear (Integer $\geq$ 0)
T3	Transverse shear thickness (Real)
NSM	Nonstructural mass per unit area (Real)
Z1, Z2	Fiber distances for stress computation, positive according to the right-hand sequence defined on the CQUAD1 card (Real)

Remarks:
1. All PQUAD1 cards must have unique property identification numbers.
2. If T3 is zero, the element is assumed to be rigid in transverse shear.
3. The membrane thickness, T1, is used to compute the structural mass for this element.

Input Data Card PQUAD2 Homogeneous Quadrilateral Property

Decription : Defines the properties of a homogeneous quadrilateral element of the structural model, including bending, membrane and transverse shear effects. Referenced by the CQUAD2 card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PQUAD2	PID	MID	T	NSM	PID	MID	T	NSM	
PQUAD2	32	16	2.98	9.0	45	16	5.29	6.32	

Field	Contents
PID	Property identification number (Integer > 0)
MID	Material identification number (Integer > 0)
T	Thickness (Real> 0.0)
NSM	Nonstructual mass per unit area (Real)

Remarks:
1. All PQUAD2 cards must have unique identification numbers.
2. The thickness used to compute membrane and transverse shear properties is T.
3. The area moment of inertia per unit width used to compute the bending stiffness is $T^3/12$.
4. Outer fiber distances of ±T/2 are assumed.
5. One or two homogeneous quadrilateral properties may be defined on a single card.

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Input Data Card PRESAX   Axisymmetric Pressure Load

Description: Defines the static pressure loading for a model containing CCØNEAX, CTRAPAX or CTRIAAX elements.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PRESAX	SID	P	RID1	RID2	PHI1	PHI2			
PRESAX	3	7.92	4	3	20.6	31.4			

Field	Contents
SID	Load set identification number (Integer > 0)
P	Pressure value (Real)
RID1, RID2	Ring identification numbers (see RINGAX card) (Integer > 0)
PHI1, PHI2	Azimuthal angles in degrees (Real, PHI1 ≠ PHI2)

Remarks:
1. This card is allowed if and only if an AXIC card is also present.
2. Load sets must be selected in the Case Control Deck (LØAD=SID) in order to be used by NASTRAN.
3. For a discussion of the conical shell problem, see Section 5.9 of the Theoretical Manual.
4. For a discussion of the axisymmetric solid problem, see Section 5.11 of the Theoretical Manual.

Input Data Card PRESPT Fluid Pressure Point

Description: Defines the location of pressure points in the fluid for recovery of pressure data.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PRESPT	IDF		IDP	φ	IDP	φ	IDP	φ	
PRESPT	14		141	0.0			142	90.0	

Field	Contents
IDF	Fluid point (RINGFL) identification number (Integer > 0)
IDP	Unique pressure point identification number (Integer > 0)
φ	Azimuthal position on fluid point, referenced by IDF, in Fluid Coordinate System (Real)

Remarks:

1. This card is allowed only if an AXIF card is also present.
2. All pressure point identification numbers must be unique with respect to other scalar, structural and fluid points.
3. The pressure points are used primarily for the identification of output data. They may also be used as points at which to measure pressure for input to control devices (see User's Manual, Section 1.7).
4. One, two or three pressure points may be defined per card.
5. Output requests for velocity and acceleration of these degrees of freedom will result in derivatives of pressure with respect to time.

NASTRAN DATA DECK

Input Data Card PRØD   Rod Property

Description: Defines the properties of a rod which is referenced by the CRØD card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PRØD	PID	MID	A	J	C	NSM			
PRØD	17	23	42.6	17.92	4.236	0.5			

Field	Contents
PID	Property identification number (Integer > 0)
MID	Material identification number (Integer > 0)
A	Area of rod (Real)
J	Torsional constant (Real)
C	Coefficient to determine torsional stress (Real)
NSM	Nonstructual mass per unit length (Real)

Remarks: 1. PRØD cards must all have unique property identification numbers.

2. For structural problems, PRØD cards may only reference MAT1 material cards.

3. For heat transfer problems, PRØD cards may only reference MAT4 or MAT5 cards.

Input Data Card PRØLATE - Prolate Spheroidal Surface

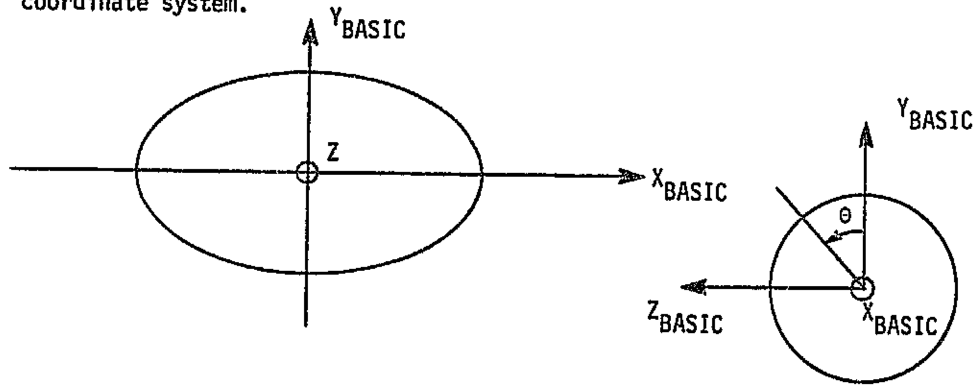
Description: Specifies a prolate spheroidal surface of the finite element model in magnetostatics problems.

Format:

1	2	3	4	5	6	7	8	9	10
PRØLATE	A	B	NSEGS	MSEGS	NN	NM	G1	G2	+P1
+P1	G3	G4	.	.	.	.	.	.	+P2
		⋮					⋮		
+PN	.	.	.	ENDT					

Field	Contents
A	Length of semi-major axis of generating ellipse (Real > 0.0)
B	Length of semi-minor axis of generating ellipse (Real > 0.0, B < A)
NSEGS	Number of segments in longitudinal direction (Integer > 2)
MSEGS	Number of segments in circumferential direction (Integer > 2)
NN,NM	Maximum n,m in series expansion (Integer, 1 < NM < NN < 30) (see Equation 10 in Section 1.15.3)
G1	Grid point identification number at left end point (Integer > 0)
G2	Grid point identification number at right end point (Integer > 0)
Gi, i ≥ 3	Grid point identification numbers of points defining the prolate spheroidal surface (Integer > 0)

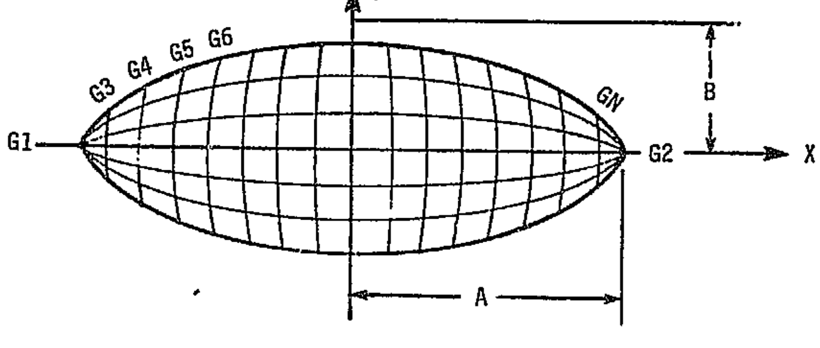
Remarks: 1. The major axis of the generating ellipse must lie on the X-axis of the basic coordinate system, the minor axis must lie on the Y-axis of the basic coordinate system, and the center of the ellipse must coincide with the origin of the basic coordinate system.



(Continued)

PRØLATE (Cont.)

2. The ordering of the grid points on the PRØLATE card is crucial and must conform to the order given in the sketch below (although the actual numbers will vary depending on the number of longitudinal segments). Note that the first set of grid points specified (starting with G3) corresponds to the start of the first circumferential segment, which must be in the X-Y plane at $\Theta = 0°$ in the prolate spheroidal coordinate system.



3. The number of longitudinal segments must be the same for every circumferential segment.

4. The PRØLATE computations are set up to handle either 180° or 360° modeling of the prolate spheroidal surface. The 180° modeling is assumed if Case Control card AXISYM contains SYMM or ANTI (with or without the ANØM option), indicating symmetry of the finite element model about the X-Y plane, and symmetry or antisymmetry, respectively of the source magnetic field and, therefore, of the anomaly potential, about the X-Y plane.

5. The total number of grid points on the PRØLATE card must be (NSEGS-1)(MSEGS+1) + 2 if 180° modeling is used and (NSEGS-1)(MSEGS) + 2 if 360° modeling is used.

6. In 360° modeling, the grid points at 0° (G3 through GN in the sketch) are also the grid points at 360°. However, on the PRØLATE card, this set of points must not be repeated. With 360° modeling, the final set of grid points on the PRØLATE card must consist of those at the end of the (MSEGS-1)th segment.

7. Only one PRØLATE card is allowed.

BULK DATA DECK

Input Data Card PSHEAR Shear Panel Property

Description: Defines the elastic properties of a shear panel. Referenced by the CSHEAR card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PSHEAR	PID	MID	T	NSM	PID	MID	T	NSM	
PSHEAR	13	2	4.9	16.2	14	6	4.9	14.7	

Field	Contents
PID	Property identification number (Integer > 0)
MID	Material identification number (Integer > 0)
T	Thickness of shear panel (Real $\neq$ 0.0)
NSM	Nonstructural mass per unit area (Real)

Remarks:

1. All PSHEAR cards must have unique identification numbers.
2. PSHEAR cards may only reference MAT1 material cards.
3. One or two shear panel properties may be defined on a single card.

NASTRAN DATA DECK

Input Data Card PTØRDRG   Toroidal Ring Property

Description: Used to define membrane and flexure (bending) properties of a toroidal ring element. Referenced by the CTØRDRG card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PTØRDRG	PID	MID	TM	TF	PID	MID	TM	TF	
PTØRDRG	2	4	0.1	0.15					

Field	Contents
PID	Property identification number (Integer > 0)
MID	Material identification number (Integer > 0)
TM	Thickness for membrane (Real > 0.0)
TF	Thickness for flexure (Real)

Remarks:
1. All PTØRDRG cards must have unique property identification numbers.
2. The material identification number MID must reference only a MAT1 or MAT3 card.
3. One or two toroidal ring properties may be defined on a single card.

Input Data Card PTRAPAX Triangular Ring Element Property

Description: Defines the properties of an axisymmetric trapezoidal cross-section ring element referenced by the CTRAPAX card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PTRAPAX	PID		MID	PHI1	PHI2	PHI3	PHI4	PHI5	+abc
PTRAPAX	5		15	0.0	5.0	6.0	7.0	8.0	+N1
+abc	PHI6	PHI7	PHI8	PHI9	PHI10	PHI11	PHI12	PHI13	+def
+N1	9.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	+2
+def	PHI14								
+N2	45.0								

Field	Contents
PID	Property identification number (Integer > 0).
MID	Material identification number (Integer > 0).
PHIi	Azimuthal coordinates (in degrees) for stress recovery (Real).

Remarks:

1. All PTRAPAX cards must have unique property identification numbers.
2. This card is allowed if and only if an AXIC card is also present.
3. PTRAPAX card may reference MAT1 or MAT3 material cards.
4. A maximum of 14 azimuthal coordinates for stress recovery may be specified.

Input Data Card PTRBSC Basic Bending Triangle Property

Description: Defines basic bending triangle (TRBSC) properties. Referenced by the CTRBSC card. No membrane properties are included.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PTRBSC	PID	MID1	I	MID2	T	NSM	Z1	Z2	
PTRBSC	3	17	6.29	4	16.	1.982	0.05	-0.05	

Field	Contents
PID	Property identification number (Integer > 0)
MID1	Material identification number for bending (Integer > 0)
I	Bending area moment of inertia per unit width (Real)
MID2	Material identification number for transverse shear (Integer ≥ 0)
T	Transverse shear thickness (Real)
NSM	Nonstructural mass per unit area (Real)
Z1, Z2	Fiber distances for shear computation, positive according to the right-hand sequence defined in the CTRBSC card (Real)

Remarks: 1. All PTRBSC cards must have unique property identification numbers.

2. If T is zero, the element is assumed to be rigid in transverse shear.

3. No structural mass is generated by this element.

Input Data Card PTRIA1 General Triangular Element Property

Description: Defines the properties of a general triangular element of the structural model, including bending, membrane and transverse shear effects. Referenced by the CTRIA1 card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PTRIA1	PID	MID1	T1	MID2	I	MID3	T3	NSM	abc
PTRIA1	32	16	2.98	9	6.45	16	5.29	6.32	QED
+bc	Z1	Z2							
+ED									

Field	Contents
PID	Property identification number (Integer > 0)
MID1	Material identification number for membrane (Integer $\geq$ 0)
T1	Membrane thickness (Real)
MID2	Material identification number for bending (Integer $\geq$ 0)
I	Area of moment of inertia per unit width (Real)
MID3	Bending material identification number for transverse shear (Integer $\geq$ 0)
T3	Transverse shear thickness (Real)
NSM	Nonstructural mass per unit area (Real)
Z1, Z2	Fiber distances for stress calculations, positive according to the right-hand sequence defined on the CTRIA1 card (Real)

Remarks:

1. All PTRIA1 cards must have unique property identification numbers.
2. If T3 is zero, the element is assumed to be rigid in transverse shear.
3. The membrane thickness, T1, is used to compute the structural mass for this element.

Input Data Card PTRIA2 Homogeneous Triangular Element Property

Description: Defines the properties of a homogeneous triangular element of the structural model, including membrane, bending and transverse shear effects. Referenced by the CTRIA2 card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PTRIA2	PID	MID	T	NSM	PID	MID	T	NSM	
PTRIA2	2	16	3.92	14.7	6	16	2.96		

Field	Contents
PID	Property identification number (Integer > 0)
MID	Material identification number (Integer > 0)
T	Thickness (Real > 0.0)
NSM	Nonstructural mass per unit area (Real)

Remarks:
1. All PTRIA2 cards must have unique identification numbers.
2. The thickness used to compute the membrane and transverse shear properties is T.
3. The area moment of inertia per unit width used to compute the bending stiffness is $T^3/12$.
4. Outer fiber distances of $\pm T/2$ are assumed.
5. One or two homogeneous triangular element properties may be defined on a single card.

Input Data Card PTRIAAX Triangular Ring Element Property

Description: Defines the properties of an axisymmetric triangular cross-section ring element referenced by the CTRIAAX card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PTRIAAX	PID		MID	PHI1	PHI2	PHI3	PHI4	PHI5	+abc
PTRIAAX	5		15	0.0	5.0	6.0	7.0	8.0	+N1
+abc	PHI6	PHI7	PHI8	PHI9	PHI10	PHI11	PHI12	PHI13	+def
+N1	9.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	+N2
+def	PHI14								
+N2	45.0								

Field	Contents
PID	Property identification number (Integer > 0).
MID	Material identification number (Integer > 0).
PHIi	Azimuthal coordinates (in degrees) for stress recovery (Real).

Remarks:

1. All PTRIAAX cards must have unique property identification numbers.
2. This card is allowed if and only if an AXIC card is also present.
3. PTRIAAX card may reference MAT1 or MAT3 material cards.
4. A maximum of 14 azimuthal coordinates for stress recovery may be specified.

Input Data Card PTRIM6 Linear Strain Triangular Membrane Property

Description: Defines the properties of a linear strain triangular membrane element. Referenced by the CTRIM6 card. No bending properties are included.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PTRIM6	PID	MID	T1	T3	T5	NSM			
PTRIM6	666	999	1.17	2.52	3.84	8.3			

Field

PID Property identification number (Integer > 0)

MID Material identification number (Integer > 0)

T1, T3, T5 Membrane thicknesses at the vertices of the element (Real)

NSM Nonstructural mass per unit area (Real)

Remarks:

1. All PTRIM6 cards must have unique property identification numbers
2. PTRIM6 cards may only reference MAT1 or MAT2 cards.
3. In general, the thickness varies linearly over the triangle. If T3 or T5 is specified 0.0 or blank, it will be set equal to T1.

Input Data Card PTRMEM Triangular Membrane Property

Description: Used to define the properties of a triangular membrane element. Referenced by the CTRMEM card. No bending properties are included.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PTRMEM	PID	MID	T	NSM	PID	MID	T	NSM	
PTRMEM	17	23	4.25	0.2					

Field	Contents
PID	Property identification number (Integer > 0)
MID	Material identification number (Integer > 0)
T	Membrane thickness (Real > 0.0)
NSM	Nonstructural mass per unit area (Real)

Remarks: 1. All PTRMEM cards must have unique property identification numbers.

2. One or two triangular membrane properties may be defined on a single card.

Input Data Card PTRPLT Triangular Plate Property

Description: Used to define the bending properties of a triangular plate element. Referenced by the CTRPLT card. No membrane properties are included.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PTRPLT	PID	MID1	I	MID2	T	NSM	Z1	Z2	
PTRPLT	17	26	4.29	16	3.9-4	2.634			

Field	Contents
PID	Property identification number (Integer > 0)
MID1	Material identification number for bending (Integer > 0)
I	Bending area moment of inertia per unit width (Real)
MID2	Material identification number for transverse shear (Integer ≥ 0)
T	Transverse shear thickness (Real)
NSM	Nonstructural mass per unit area (Real)
Z1, Z2	Fiber distances for stress computation, positive according to the right-hand sequence defined on the CTRPLT card (Real)

Remarks:
1. All PTRPLT cards must have unique property identification numbers.
2. If T is zero, the element is assumed to be rigid in transverse shear.
3. No structural mass is generated by this element.

Input Data Card PTRPLT1 Triangular Plate Property

Description: Defines the bending properties of a higher order triangular plate element. Referenced by the CTRPLT1 card. No membrane properties are included.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PTRPLT1	PID	MID1	R1	R3	R5	MID2	TS1	TS3	abc
PTRPLT1	15	25	20.0	30.0	40.0	35	3.0	1.15	PQR

+bc	TS5	NSM	Z11	Z21	Z13	Z23	Z15	Z25	
+QR	1.0	9.0	1.5	-1.5	2.0	-2.0	+2.5	-2.5	

Field	Contents
PID	Property identification number (Integer > 0)
MID1	Material identification number for bending (Integer > 0)
R1, R3, R5	Area moment of inertia per unit width at the grid points G1, G3, and G5 respectively (Real > 0.0) ; $R1 = T_1^3/12$, $R3 = T_3^3/12$, $R5 = T_5^3/12$ where T_1, T_3, and T_5 are the thicknesses of the element at the vertices, respectively
MID2	Material identification number for transverse shear (Integer > 0)
TS1, TS3, TS5	Transverse shear thicknesses at the grid points G1, G3, and G5, respectively (Real)
NSM	Nonstructural mass per unit area (Real)
Z11, Z21, Z13 Z23, Z15, Z25	Fiber distances for stress computation at grid points G1, G3, and G5, respectively; positive according to the right-hand sequence defined on the CTRPLT1 card (Real)

Remarks:
1. All PTRPLT1 cards must have unique property identification numbers.
2. If TS1 is zero, the element is assumed to be rigid in transverse shear.
3. If TS3 or TS5 is 0.0 or blank, it will be set equal to TS1.
4. If I3 or I5 is 0.0 or blank, it will be set equal to I1.
5. The stresses at the centroid will be computed at the top and bottom fibers. The stresses at G1, G3 and G5 will be computed at the locations defined on the property card (if given).
6. The continuation card is required, even if blank.

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NASTRAN DATA DECK

Input Data Card PTRSHL Higher Order Triangular Shell Element Property

Description: Defines the membrane bending and transverse shear properties of a higher order triangular shell element. Referenced by the CTRSHL card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PTRSHL	PID	MID1	T1	T3	T5	MID2	I1	I3	abc
PTRSHL	10	20	3.0	6.0	4.0	30	2.25	18.0	PQR
+bc	I5	MID3	TS1	TS3	TS5	NSM	Z11	Z21	def
+QR	5.33	40	2.5	5.0	3.5	50.0	1.5	-1.5	STU
+ef	Z13	Z23	Z15	Z25					
+TU	3.0	-3.0	2.0	-2.0					

Field	Contents
PID	Property identification number (Integer > 0)
MID1	Material identification number for membrane (Integer > 0)
T1, T3, T5	Thickness at vertices 1, 3, and 5 of the element, respectively (Real ≥ 0.0)
MID2	Material identification number for bending (Integer > 0)
I1, I3, I5	Area moments of inertia per unit width at the vertices 1, 3, and 5 of the of the element, respectively (Real ≥ 0.0)
MID3	Material identification number for transverse shear (Integer ≥ 0)
TS1, TS3, TS5	Transverse shear thickness at the vertices 1, 3, and 5 of the element, respectively (Real ≥ 0.0)
NSM	Nonstructural mass per unit area (Real)
Z11, Z21, Z13, Z23, Z15, Z25	Fiber distances for stress computation at grid points G1, G3, and G5 respectively, positive according to the right-hand sequence defined on the CTRSHL card (Real ≥ 0.0)

Remarks:

1. All PTRSHL cards must have unique property identification numbers.
2. If T3 or T5 are equal to 0.0 or blank, they will be set equal to T1.
3. If I3 or I5 are equal to 0.0 or blank, they will be set equal to I1.
4. If TS3 or TS5 are equal to 0.0 or blank, they will be set equal to TS1.
5. If TS1 is 0.0 or blank, the element is assumed to be rigid in transverse shear.
6. The stresses at the centroid will be computed at the top and bottom fibers. The stresses at G1, G3, and G5 will be computed at the locations defined on the property card (if given).
7. Both continuation cards are required, even if blank.

Input Data Card PTUBE Tube Property

Description: Defines the properties of a thin-walled cylindrical tube element. Referenced by the CTUBE card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PTUBE	PID	MID	ØD	T	NSM				
PTUBE	2	6	6.29	0.25					

Field	Contents
PID	Property identification number (Integer > 0)
MID	Material identification number (Integer > 0)
ØD	Outside diameter of tube (Real > 0.0)
T	Thickness of tube (Real; T ≤ 1/2 ØD)
NSM	Nonstructural mass per unit length (Real)

Remarks:
1. If T is zero, a solid circular rod is assumed.
2. PTUBE cards must all have unique property identification numbers.
3. For structural problems, PTUBE cards may only reference MAT1 material cards.
4. For heat transfer problems, PTUBE cards may only reference MAT4 or MAT5 material cards.

NASTRAN DATA DECK

Input Data Card PTWIST Twist Panel Property

Description: Defines the elastic properties of a twist panel element. Referenced by the CTWIST card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PTWIST	PID	MID	T	NSM	PID	MID	T	NSM	
PTWIST	4	6	2.3	9.4	5	6	1.6		

Field	Contents
PID	Property identification number (Integer > 0)
MID	Material identification number (Integer > 0)
T	Thickness of twist panel (Real $\neq$ 0.0)
NSM	Nonstructural mass per unit area (Real)

Remarks: 1. All PTWIST cards must have unique identification numbers.

2. PTWIST cards may only reference MAT1 material cards.

3. One or two twist panel properties may be defined on a single card.

Input Data Card PVISC Viscous Element Property

Description: Defines the viscous properties of a one-dimensional viscous element which is used to create viscous elements by means of the CVISC card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PVISC	PID	C1	C2		PID	C1	C2		
PVISC	3	6.2	3.94						

Field	Contents
PID	Property identification number (Integer > 0)
C1, C2	Viscous coefficients for extension and rotation (Real)

Remarks:
1. Used for both extensional and rotational viscous elements.
2. Has meaning for dynamics problems only.
3. Viscous properties are material independent; in particular, they are temperature-independent.
4. One or two viscous element properties may be defined on a single card.
5. Used only for direct formulation of dynamic analyses.

NASTRAN DATA DECK

Input Data Card QBDY1 Boundary Heat Flux Load

Description: Defines a uniform heat flux into HBDY elements.

Format and Example:

1	2	3	4	5	6	7	8	9	10
QBDY1	SID	QO	EID	EID	EIDm	"THRU"	EIDn	EID	abc
QBDY1	109	1.-5	721	723	731	THRU	790	796	ABC

+bc	EID	-etc.-							def
+BC	801								

-etc.-

Field	Contents
SID	Load set identification number (Integer > 0)
QO	Heat flux into element (Real)
EID EIDm EIDn	HBDY elements (Integer > 0; EIDm < EIDn)

Remarks:

1. QBDY1 cards must be selected in the Case Control Deck (LØAD = SID) to be used in statics. The power contributed into an element via this card is given by the equation:

$$P_{in} = [(\text{Effective area})\cdot QO+A]\cdot F(t-\tau) \quad ,$$

where effective area is taken from PHBDY cards and A is taken from DAREA card.

2. QBDY1 cards must be referenced on a TLØADi card for use in transient analysis. The power contributed into an element via this card is given by the equation:

$$P_{in}(t) = [(\text{Effective area})\cdot QO\cdot F(t-\tau) \quad ,$$

where the function of time, $F(t-\tau)$, is specified on a TLØAD or TLØAD2 card.

3. QO is positive for heat input.

4. EID may be specified as individual references or as sequential lists ("THRU" sequences) and the two methods may be used interchangeably. The only restriction is that integer values must appear in fields 4 and 9 of the QBDY1 card and in fields 2 and 9 of each continuation card (if all fields are used).

Input Data Card QBDY2 Boundary Heat Flux Load

Description: Defines grid point heat flux into an HBDY element.

Format and Example:

1	2	3	4	5	6	7	8	9	10
QBDY2	SID	EID	Q01	Q02	Q03	Q04			
QBDY2	109	721	1.-5	1.-5	2.-5	2.-5			

Field	Contents
SID	Load set identification number (Integer > 0)
EID	Identification number of an HBDY element (Integer > 0)
Q0i	Heat flux at the i^{th} grid point on the referenced HBDY element (Real or blank)

Remarks:

1. QBDY2 cards must be selected in Case Control (LØAD = SID) to be used in statics. The power contributed into each point, i, on an element via this card is given by

$$P_i = AREA_i \cdot Q0_i .$$

2. QBDY2 cards must be referenced on a TLØAD card for use in transient. All connected grid points will have the same time function, but may have individual delays. The power contributed into each point, i, or an element via this card is given by

$$P_i(t) = AREA_i \cdot Q0_i \cdot F(t-\tau_i),$$

where $F(t-\tau_i)$ is a function of time specified on a TLØAD1 or TLØAD2 card.

3. $Q0_i$ is positive for heat flux input to the element.

Input Data Card QHBDY   Boundary Heat Flux Load

Description: Defines a uniform heat flux into a set of grid points.

Format and Example:

1	2	3	4	5	6	7	8	9	10
QHBDY	SID	FLAG	QO	AF	G1	G2	G3	G4	
QHBDY	120	LINE	1.5+3	.75	13	15			

Field	Contents
SID	Load set identification number (Integer > 0)
FLAG	Type of area involved (must be one of the following "PØINT," "LINE," "REV," "AREA3," "AREA4")
QO	Heat flux into an area (Real)
AF	Area factor depends on type (Real > 0.0 or blank)
G1,G2,G3,G4	Grid point identification of connected points (Integer > 0 or blank)

Remarks:

1. The heat flux applied to the area is transformed to loads on the points. These points need not correspond to an HBDY element.

2. The flux is applied to each point, i, by the equation

$$P_i = AREA_i \cdot QO,$$

where QO is positive for heat input, and $AREA_i$ is the portion of the total area associated with point i.

3. In statics, the load is applied with the Case Control request: LØAD = SID. In dynamics, the load is applied by reference on a TLØADi data card. The load at each point will be multiplied by the function of time $F(t-\tau_i)$ defined on the TLØADi card. τ_i is the delay factor for each point.

4. The number of connected points for the five types are 1(PØINT), 2(LINE,REV), 3(AREA3), 4(AREA4). Any unused Gi entries must be on the right.

5. The area factor AF is used to determine the effective area for the PØINT and LINE types. It equals the area and the effective width, respectively. It is ignored for the other types, which have their area defined implicitly.

6. The type flag defines a surface in the same manner as the CHBDY data card. For physical descriptions of the geometry involved, see the CHBDY description.

Input Data Card QVECT Thermal Flux Vector Load

Description: Defines thermal flux vector from a distant source into HBDY elements.

Format and Example:

1	2	3	4	5	6	7	8	9	10
QVECT	SID	Q0	E1	E2	E3	EID1	EID2	EID3	abc
QVECT	333	1.-2	-1.0	0.0	0.0	721	722	723	ABC
+bc	EID4	EID5	-etc.-						def
+BC	724								

-etc.-

Field	Contents
SID	Load set identification number (Integer > 0)
Q0	Magnitude of thermal flux vector (Real)
E1,E2,E3	Vector components (in basic coordinate system) of the thermal flux vector (Real or Integer > 0). The total flux is given by Q = Q0{E1,E2,E3}
EIDi	Element identification numbers of HBDY elements irradiated by the distant source (Integer > 0)

Remarks: 1. For statics, the load set is selected in the Case Control Deck (LØAD = SID). The power contributed into an element via this card is given by

$$P_{in} = -\alpha A(\bar{e}\cdot\bar{n})\cdot Q0,$$

where:

α = absorbtivity
A = area of HBDY element
$\bar{e}$ = vector of real numbers E1, E2, E3 of
$\bar{n}$ = positive normal vector of element, see CHBDY data card description
$(\bar{e}\cdot\bar{n})$ = 0 if the vector product is positive (i.e., the flux is coming from behind the element)

2. For transient analysis, the load set (SID) is selected by a TLØADi card which defines a load function of time. The power contributed into the element via this card is given by

$$P_{\ell}(t) = -\alpha A(\bar{e}(t)\cdot\bar{n})\cdot Q0\cdot F(t-\tau),$$

where:

α,A, and $\bar{n}$ are the same as the statics case
$\bar{e}(t)$ = vector of three functions of time, which may be given on TABLEDi data cards. If E1, E2, or E3 is an integer, it is the table identification number. If E1, E2, or E3 is a real number, its value is used directly; if Ei is blank, its value is zero.
$F(t-\tau)$ is a function of time specified or referenced by the parent TLØAD1 or TLØAD2 card. The value τ is calculated for each loaded point.

(Continued)

QVECT (Cont.)

3. If the referenced HBDY element is of TYPE = ELCYL, the power input is an exact integration over the area exposed to the thermal flux vector.

4. If the referenced HBDY element is of TYPE = REV, the vector should be parallel to the basic z axis.

5. If a sequential list of elements is desired, fields 7, 8, and 9 may specify the first element, the BCD string "THRU", and the last element. No subsequent data is allowed with this option.

Input Data Card QVØL   Volume Heat Addition

Description: Defines a rate of internal heat generation in an element.

Format and Example:

1	2	3	4	5	6	7	8	9	10
QVØL	SID	QV	EID	EID	EIDm	"THRU"	EIDn	EID	abc
QVØL	333	1.+2	301	303	317	THRU	345	416	ABC

+bc	EID7	-etc.-							def
+BC	527								

-etc.-

Field	Contents
SID	Load set identification number (Integer > 0)
QV	Power input per unit volume produced by a heat conduction element (Real)
EID EIDm EIDn	Heat conduction element identification numbers (Integer > 0; EIDm < EIDn)

Remarks:

1. In statics, the load is applied with the Case Control request, LØAD = SID . The equivalent power contributed via this card into each grid point, i, connected to each element listed, is given by

$$P_i = QV \cdot VØL_i \quad ,$$

where $VØL_i$ is the portion of the volume associated with point i and QV is positive for heat generation.

2. In dynamics, the load is requested by reference on a TLØADi card. The equivalent power contributed via this card into each grid point i, connected to each element listed, is

$$P_i = QV \cdot VØL_i \cdot F(t-\tau_i) \quad ,$$

where $VØL_i$ is the portion of the volume associated with point i and $F(t-\tau_i)$ is the function of time defined by a TLØADi card. τ_i is the delay for each point i.

3. EID may be specified as individual references or as sequential lists ("THRU" sequences) and the two forms may be used interchangeably. The only restriction is that integer values must appear in fields 4 and 9 of the QVØL card and in fields 2 and 9 of each continuation card (if all fields are used).

Input Data Card RADLST List of Radiation Area:

Description: A list of HBDY identification numbers given in the same order as the columns of the RADMTX matrix.

Format and Example:

1	2	3	4	5	6	7	8	9	10
RADLST	EID1	EID2	EID3	EID4	EID5	EID6	EID7	EID8	abc
RADLST	10	20	30	50	31	41	THRU	61	ABC
+bc	EID9	-etc.-							def
+BC	71								

-etc.-

Field	Contents
EIDi	The element identification numbers of the HBDY elements, given in the order that they appear in the RADMTX matrix (Integer > 0 or BCD "THRU")

Remarks:

1. This card is required if a RADMTX is defined.

2. Only one RADLST card string is allowed in a data deck.

3. If a group of the elements are sequential, any field except 2 and 9 may contain the BCD word "THRU". Element Id numbers will be generated for every integer between the value of the previous field and the value of the subsequent field. The values must increase, however.

4. Any element may be listed more than once. For instance, if both sides of a panel are radiating, each side may participate in a different part of the view factor matrix.

Input Data Card RADMTX Radiation Matrix

Description: Matrix of radiation exchange coefficients (area times view factor) for nonlinear heat transfer analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
RADMTX	INDEX	Fi,i	Fi+1,i	Fi+2,i	Fi+3,i	Fi+4,i	Fi+5,i	Fi+6,i	abc
RADMTX	3	0.	9.3	17.2	16.1	.1	0.	6.2	ABC
+bc	Fi+7,i	-etc.-							def
+BC	6.2								

-etc.-

Field	Contents
INDEX	The column number of the matrix (Integer > 0)
Fi+k,i	The matrix values (Real), starting on the diagonal, continuing down the column. A group of zero's at the bottom of the column may be omitted. A blank field will end the column, which disallows imbedded blank fields.

Remarks:

1. The INDEX numbers go from 1 thru NA, where NA is the number of radiating areas.

2. The radiation exchange coefficient matrix is symmetric, and only the lower triangle is input. Column 1 is associated with the HBDY element first listed on the RADLST card, Column 2 for the next, etc. Null columns need not be entered.

3. $$P_i = \sum_{j=1}^{NA} F_{ij} q_j$$

   P_i = total irradiation into element i

   q_j = radiosity (per unit area) at j

   F_{ij} = radiation matrix (units of area)

4. A column may only be specified once.

5. An element identification appearing on a RADLIST card that is not defined on a RADMTX card or is only partially defined, will cause the missing terms of the matrix column to be filled with zeros. This implies an infinite heat sink (radiation loss) is present.

Input Data Card RANDPS   Power Spectral Density Specification

Description: Defines load set power spectral density factors for use in Random Analysis having the frequency dependent form

$$S_{jk}(F) = (X + iY)\ G(F)$$

Format and Example:

1	2	3	4	5	6	7	8	9	10
RANDPS	SID	J	K	X	Y	TID			
RANDPS	5	3	7	2.0	2.5	4			

Field	Contents
SID	Random analysis set identification number (Integer > 0)
J	Subcase identification number of excited load set (Integer > 0)
K	Subcase identification number of applied load set (Integer $\geq$ 0; K $\geq$ J)
X,Y	Components of complex number (Real)
TID	Identification number of a TABRNDi card which defines G(F) (Integer $\geq$ 0)

Remarks:

1. If J = K, then Y must be 0.0.
2. For TID = 0, G(F) = 1.0.
3. Set identification numbers must be selected in the Case Control Deck (RANDØM=SID) to be used by NASTRAN.
4. Only 20 unique sets may be defined. As many RANDPS cards as desired with the same SID may be input, however.
5. RANDPS can only reference subcases included within a single loop (change in direct matrix input is not allowed).

Input Data Card RANDT1 Autocorrelation Function Time Lag

Description: Defines time lag constants for use in random analysis autocorrelation function computation.

Format and Example:

1	2	3	4	5	6	7	8	9	10
RANDT1	SID	N	TO	TMAX					
RANDT1	5	10	3.2	9.6					

Field	Contents
SID	Random analysis set identification number (Integer > 0)
N	Number of time lag intervals (Integer > 0)
TO	Starting time lag (Real ≥ 0.0)
TMAX	Maximum time lag (Real > TO)

Remarks: 1. At least one RANDPS card must be present with the same set identification number.

2. The time lags defined on this card are given by

$$T_i = T_o + \frac{T_{max} - T_o}{N}(i - 1), \qquad i = 1, N + 1$$

3. Time lag sets must be selected in the Case Control Deck (RANDØM=SID) to be used by NASTRAN.

NASTRAN DATA DECK

Input Data Card RELES   Release Substructure Connectivities

Description: Defines sets of component degrees of freedom at substructure grid points which are not to be connected.

Format and Example:

1	2	3	4	5	6	7	8	9	10
RELES	SID	NAME	G1	C1	G2	C2	G3	C3	def
RELES	6	WINGRT	17	456	18	456	21	123	DEF
+ef	G4	C4	etc.		GN	CN			
+EF	25	456							

Field	Contents
SID	Set identification number (Integer > 0)
NAME	Name of basic substructure (BCD)
Gi	Grid or scalar point identification number (Integer > 0)
Ci	Component number - Any unique combination of the digits 1 - 6 (with no imbedded blanks) when the Gi are grid points, or null if they are scalar points.

Remarks:
1. The RELES data will override any connections generated automatically from geometry and any connections defined on CØNCT data cards.
2. The RELES data will not override connections defined on the CØNCT1 data card.
3. Connectivity sets must be selected in the Substructure Control Deck (CØNNECT=SID) to be used by NASTRAN. Note that 'CØNNECT' is a subcommand of the substructure CØMBINE command.
4. Connectivities defined during previously executed CØMBINE operations will be retained and may be referenced by the grid point ID and component of any one of the basic substructures associated with that connectivity.

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Input Data Card REMFLUX - Remanent Flux Density

Description: Specifies remanent flux density for selected elements.

Format and Example:

1	2	3	4	5	6	7	8	9	10
REMFLUX	SID	CID	BRX	BRY	BRZ	EID1	EID2	EID3	
REMFLUX	2		1.	2.	3.	1	2	3	

Alternate Form:

REMFLUX	SID	CID	BRX	BRY	BRZ	EID1	"THRU"	EID2	
REMFLUX	2		1.	2.	3.	1	THRU	3	

Field	Contents
SID	Load set identification number (Integer > 0)
CID	Coordinate system identification number (Integer > 0)
BRX,BRY,BRZ	Remanent flux density in coordinate system CID (Real)
EID1,EID2,EID3	Element identification numbers (Integer > 0)

Remarks:

1. Load sets must be selected in the Case Control Deck (LØAD=SID) to be used by NASTRAN.

2. If the alternate form of the card is used, all elements between EID1 and EID2 need not exist, but sufficient core must be available for 5(EID2 - EID1 + 1) words.

3. REMFLUX cards may not have the same load set identification number as SPCFLD, CEMLØØP, GEMLØØP or MDIPØLE cards. However, they may be combined on a LØAD card or a SUBCØM card.

4. CID must presently be 0 or blank.

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Input Data Card RFØRCE Rotational Force

Description: Defines a static loading condition due to a centrifugal force field.

Format and Example:

1	2	3	4	5	6	7	8	9	10
RFØRCE	SID	G	CID	A	N1	N2	N3		
RFØRCE	2	5		-6.4	0.0	0.0	1.0		

Field	Contents
SID	Load set identification number (Integer > 0)
G	Grid point identification number (Integer $\geq$ 0)
CID	Coordinate system defining rotation direction (Integer $\geq$ 0 or blank)
A	Scale factor for rotational velocity in revolutions per unit time (Real)
N1, N2, N3	Rectangular components of rotation direction vector (Real; $N1^2 + N2^2 + N3^2 > 0.0$) The vector defined will act at point G.

Remarks:

1. G = 0 means the basic coordinate system origin.
2. CID = 0 means the basic coordinate system.
3. Load sets must be selected in the Case Control Deck (LØAD=SID) to be used by NASTRAN.
4. Rotational force sets can be combined with other static loads only by using the LØAD bulk data card.
5. The load vector generated by this card can be printed with an ØLØAD request in the Case Control Deck.
6. For elements with lumped mass, the centrifugal acceleration is calculated at the center of the lumped mass. Grid point offsets of the mass such as those defined with BAR and CØNM2 elements are taken into account.
7. For elements using the coupled "consistent" mass option (CØUPMASS) or those with implicit coupled mass matrices such as IHEXi and TRIAAX elements, the centrifugal accelerations are calculated based on grid point locations. This acceleration vector is then multiplied by the mass matrix to generate loads. Therefore, for greater accuracy, elements near the axis of rotation should be kept small to best represent the actual acceleration field.
8. When applying a rotational force to an axisymmetric element, G and CID must be 0 or blank; N1 and N2 must be 0.0.

Input Data Card RINGAX Axisymmetric Ring

Description: Defines a ring for a model containing CCØNEAX, CTRAPAX or CTRIAAX elements.

Format and Example:

1	2	3	4	5	6	7	8	9	10
RINGAX	ID		R	Z			PS		
RINGAX	3		2.0	-10.0			162		

Field	Contents
ID	Ring identification number ($1 \leq$ Integer $< 10^6$)
R	Ring radius (Real > 0.0)
Z	Ring axial location (Real)
PS	Permanent single-point constraints (any unique combination of the digits 1-6)

Remarks:
1. This card is allowed if and only if an AXIC card is also present.
2. The number of degrees of freedom defined is (6-PS)·H where H is the harmonic count and PS is the number of digits in field 8. (See AXIC card.)
3. RINGAX identification numbers must be unique with respect to all other PØINTAX, RINGAX and SECTAX identification numbers.
4. The fourth and sixth degrees of freedom must be constrained when transverse shear flexibility is not included for the conical shell.
5. For a discussion of the conical shell problem see Section 5.9 of the Theoretical Manual.
6. For a discussion of the axisymmetric solid problem, see Section 5.11 of the Theoretical Manual.

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Input Data Card RINGFL Axisymmetric Fluid Point

Description: Defines a circle (fluid point) in an axisymmetric fluid model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
RINGFL	IDF	X1	X2	X3	IDF	X1	X2	X3	
RINGFL	3	1.0		30.0					

Field	Contents
IDF	Unique identification number of the fluid point (Integer, $0 < \text{IDF} < 10^5$)
X1,X2,X3	Coordinates of point in fluid coordinate system defined on AXIF card (Real; X1 > 0.0)

Remarks:
1. This card is allowed only if an AXIF card is also present.
2. All fluid point identification numbers must be unique with respect to other scalar, structural and fluid points.
3. X1, X2, X3 are (r, ϕ, z) for a cylindrical coordinate system and (ρ, Θ, ϕ) for a spherical coordinate system. Θ and ϕ are in degrees. The value of Θ must be greater than zero. The value of ϕ must be blank or zero.
4. One or two fluid points may be defined per card.

Input Data Card RLØAD1 Frequency Response Dynamic Load

Description: Defines a frequency dependent dynamic load of the form

$$\{P(f)\} = \{A[C(f) + iD(f)]\, e^{i\{\theta - 2\pi f\tau\}}\}$$

for use in frequency response problems.

Format and Example:

1	2	3	4	5	6	7	8	9	10
RLØAD1	SID	L	M	N	TC	TD			
RLØAD1	5	3	6	9	1	2			

Field	Contents
SID	Set identification number (Integer > 0)
L	Identification number of DAREA or DAREAS and LØADC card set which defines A (Integer > 0)
M	Identification number of DELAY or DELAYS card set which defines τ (Integer $\geq$ 0)
N	Identification number of DPHASE or DPHASES card set which defines θ (Integer $\geq$ 0)
TC	Set identification number of TABLEDi card which gives C(f) (Integer $\geq$ 0; TC + TD > 0)
TD	Set identification number pf TABLEDi card which gives D(f) (Integer $\geq$ 0; TC + TD > 0)

Remarks:

1. If any of M, N, TC or TD are blank or zero, the corresponding τ, θ, C(f), or D(f) will be zero
2. Dynamic load sets must be selected in the Case Control Deck (DLØAD=SID) to be used by NASTRAN.
3. RLØAD1 loads may be combined with RLØAD2 loads only by specification on a DLØAD card. That is, the SID on a RLØAD1 card may not be the same as that on a RLØAD2 card.
4. SID must be unique for all RLØAD1, RLØAD2, TLØAD1 and TLØAD2 cards.
5. With automated multi-stage substructuring, DAREAS cards may only reference degrees of freedom in the boundary set of the solution structure.
6. When L references LØADC cards, DAREAS cards with the same set identification and non-zero loads must also exist.

Input Data Card RLØAD2   Frequency Response Dynamic Load

Description: Defines a frequency dependent dynamic load of the form

$$\left\{P(f)\right\} = \left\{AB(f)e^{i\{\phi(f) + \theta - 2\pi f\tau\}}\right\}$$

for use in frequency response problems.

Format and Example:

1	2	3	4	5	6	7	8	9	10
RLØAD2	SID	L	M	N	TB	TP			
RLØAD2	5	3	6	21	7	2			

Field	Contents
SID	Set identification number (Integer > 0)
L	Identification number of DAREA or DAREAS and LØADC card set which defines A (Integer > 0)
M	Identification number of DELAY or DELAYS card set which defines τ (Integer $\geq$ 0)
N	Identification number of DPHASE or DPHASES card set which defines θ in degrees (Integer $\geq$ 0)
TB	Set identification number of TABLEDi card which gives B(f) (Integer $\geq$ 0)
TP	Set identification number of TABLEDi card which gives ϕ(f) in degrees (Integer $\geq$ 0)

Remarks:
1. If any of M, N or TP are zero, the corresponding τ, θ or ϕ(f) will be zero.
2. Dynamic load sets must be selected in the Case Control Deck (DLØAD=SID) to be used by NASTRAN.
3. RLØAD2 loads may be combined with RLØAD1 loads only by specification on a DLØAD card. That is, the SID on a RLØAD2 card may not be the same as that on a RLØAD1 card.
4. SID must be unique for all RLØAD1, RLØAD2, TLØAD1 and TLØAD2 cards.
5. With automated multi-stage substructuring, DAREAS cards may only reference degrees of freedom in the boundary set of the solution structure.
6. When L references LØADC cards, DAREAS cards with the same set identification and non-zero loads must also exist.

Input Data Card SECTAX Axisymmetric Sector

Description: Defines a sector of a model containing CCØNEAX, CTRAPAX or CTRIAAX elements.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SECTAX	ID	RID	R	PHI1	PHI2				
SECTAX	1	2	3.0	30.0	40.0				

Field	Contents
ID	Sector identification number (Unique Integer > 0)
RID	Ring identification number (see RINGAX)(Integer > 0)
R	Effective radius (Real)
PHI1, PHI2	Azimuthal limits of sector in degrees (Real)

Remarks: 1. This card is allowed if and only if an AXIC card is also present.

2. SECTAX identification numbers must be unique with respect to all other PØINTAX, RINGAX and SECTAX identification numbers.

3. For a discussion of the conical shell problem, see Section 5.9 of the Theoretical Manual.

4. For a discussion of the axisymmetric solid problem, see Section 5.11 of the Theoretical Manual.

Input Data Card SEQEP Extra Point Resequencing

Description: The purpose of this card is to allow the user to reidentify the formation sequence of the extra points of his structural model in such a way as to optimize bandwidth which is essential for efficient solutions by the displacement method.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SEQEP	ID	SEQID	ID	SEQID	ID	SEQID	ID	SEQID	
SEQEP	5392	15.6			2	1.9.2.6	3	2	

Field	Contents
ID	Extra point identification number (Integer > 0)
SEQID	Sequenced identification number (a special number described below)

Remarks:

1. ID is any extra point identification number which is to be reidentified for sequencing purposes. The sequence number is a special number which may have any of the following forms where X is a decimal integer digit - XXXX.X.X.X, XXXX.X.X, XXXX.X or XXXX where any of the leading X's may be omitted. This number must contain no imbedded blanks.
2. If the user wishes to insert an extra point between two already existing grid, scalar and/or extra points, such as 15 and 16, for example, he would define it as, say 5392, and then use this card to insert extra point number 5392 between them by equivalencing it to, say, 15.6. All output referencing this point will refer to 5392.
3. The SEQID numbers must be unique and may not be the same as a point ID which is not being changed. No extra point ID may be referenced more than once.
4. No continuation cards (small field or large field) are allowed with either the SEQGP or the SEQEP card.
5. From one to four extra points may be resequenced on a single card.

Input Data Card SEQGP Grid and Scalar Point Resequencing

Description: Used to order the grid points and user-supplied scalar points of the problem. The purpose of this card is to allow the user to reidentify the formation sequence of the grid and scalar points of his structural model in such a way as to optimize bandwidth which is essential for efficient solutions by the displacement method.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SEQGP	ID	SEQID	ID	SEQID	ID	SEQID	ID	SEQID	
SEQGP	5392	15.6			2	1.9.2.6	3	2	

Field	Contents
ID	Grid or scalar point identification number (Integer > 0)
SEQID	Sequenced identification number (a special number described below)

Remarks:

1. ID is any grid or scalar point identification number which is to be reidentified for sequencing purposes. The grid point sequence number (SEQID) is a special number which may have any of the following forms where X is a decimal integer digit - XXXX.X.X.X, XXXX.X.X, XXXX.X or XXXX where any of the leading X's may be omitted. This number must contain no imbedded blanks.
2. If the user wishes to insert a grid point between two already existing grid points, such as 15 and 16, for example, he would define it as, say 5392, and then use this card to insert grid point number 5392 between them by equivalencing it to, say 15.6. All output referencing this point will refer to 5392.
3. The SEQID numbers must be unique and may not be the same as a point ID which is not being changed. No grid point ID may be referenced more than once.
4. No continuation cards (small field or large field) are allowed with either the SEQGP or the SEQEP card.
5. From one to four grid or scalar points may be resequenced on a single card.

Input Data Card SET1 Grid Point List

Description: Defines a set of structural grid points by a list.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SET1	SID	G1	G2	G3	G4	G5	G6	G7	ABC
SET1	3	31	62	93	124	16	17	18	ABC
+BC	G8	--etc.-							
+BC	19								

Field Contents

SID Set of identification numbers (Integer > 0).

G1,G2, etc. List of structural grid points (Integer > 0 or "THRU").

Remarks: 1. These cards are referenced by the SPLINE data cards.

2. When using the "THRU" option, all intermediate grid points must exist. The word "THRU" may not appear in field 3 or 9 (2 or 9 for continuation cards.)

Input Data Card SET2 Grid Point List

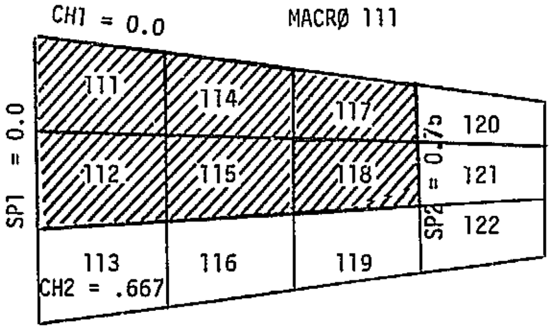
Description: Defines a set of structural grid points in terms of aerodynamic macro elements.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SET2	SID	MACRØ	SP1	SP2	CH1	CH2	ZMAX	ZMIN	
SET2	3	111	.0	.75	0.	.667	1.0	-3.51	

Field	Contents
SID	Set identification number (Integer > 0).
MACRØ	Element identification number of an aero macro element (Integer > 0).
SP1,SP2	Lower and higher span division points defining prism containing set (-.01 < Real < 1.01)
CH1,CH2	Lower and higher chord division points defining prism containing set (-.01 < Real < 1.01)
ZMAX,ZMIN	Top and bottom z coordinates (using right-hand rule with the order the corners as listed on a CAERØ1 card) of the prism containing set (Real). Usually ZMAX $\geq$ 0, ZMIN $\leq$ 0.

Remarks:
1. These cards are referenced by the SPLINEi data cards.
2. Every grid point, within the defined prism and within the height range, will be in the set. For example,



The shaded area in the figure defines the cross-section of the prism for the sample data given above. Points exactly on the boundary may be missed, hence, to get the area of the macro element, use SP1 = -.01, SP2 = 1.01, etc.

3. A zero value for ZMAX or ZMIN implies infinity is to be used.
4. To find the (internal) grid ID's found, use DIAG 18.

NASTRAN DATA DECK

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Input Data Card SLBDY Slot Boundary List

Description: Defines a list of slot points which lie on an interface between an axisymmetric fluid and a set of evenly spaced radial slots.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SLBDY	RHØ	M	ID1	ID2	ID3	ID4	ID5	ID6	abc
SLBDY	0.002	6	16	17	18	25	20	21	+BDY

+bc	ID7	-etc.-							+def
+BDY	22								

- etc. -

Field	Contents
RHØ	Density of fluid at boundary (Real > 0.0, or blank)
M	Number of slots (Integer ≥ 0, or blank)
IDj	Identification numbers of GRIDS slot points at boundary with axisymmetric fluid cavity, j = 1,2,...,J (Integer > 0)

Remarks:

1. This card is allowed only if an AXSLØT card is also present.
2. If RHØ or M is "blank" the default value on the AXSLØT card is used. The effective value must not be zero for RHØ. If the effective value of M is zero, no matrices at the boundary will be generated.
3. The order of the list of points determines the topology of the boundary. The points are listed sequentially as one travels along the boundary in either direction. At least two points must be defined.
4. More than one logical boundary card may be used.

Input Data Card SLØAD   Static Scalar Load

Description: Used to apply static loads to scalar points.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SLØAD	SID	S	F	S	F	S	F		
SLØAD	16	2	5.9	17	-6.3	14	-2.93		

Field	Contents
SID	Load set identification number (Integer > 0)
S	Scalar point identification number (Integer > 0)
F	Load value (Real)

Remarks: 1. Load sets must be selected in the Case Control Deck (LØAD=SID) to be used by NASTRAN.

2. Up to three scalar loads may be defined on a single card.

Input Data Card SPC Single-Point Constraint

Description: Defines sets of single-point constraints and enforced displacements.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SPC	SID	G	C	D	G	C	D		
SPC	2	32	436	-2.6	5		+2.9		

Field	Contents
SID	Identification number of single-point constraint set (Integer > 0)
G	Grid or scalar point identification number (Integer > 0)
C	Component number (Any unique combination of the digits 1-6 (with no imbeded blanks) when point identification numbers are grid points; zero or blank if point identification numbers are scalar points)
D	Value of enformed displacement for all coordinates designated by G and C (Real)

Remarks:

1. A coordinate referenced on this card may not appear as a dependent coordinate in a multipoint constraint relation (MPC card) or as a degree of freedom on a rigid element (CRIGD1, CRIGD2, CRIGD3, CRIGDR), nor may it be referenced on a SPC1, ØMIT, ØMIT1 or SUPØRT card. D must be 0.0 for dynamics problems.
2. Single-point forces of constraint are recovered during stress data recovery.
3. Single-point constraint sets must be selected in the Case Control Deck (SPC=SID) to be used by NASTRAN.
4. From one to twelve single-point constraints may be defined on a single card.
5. SPC degrees of freedom may be redundantly specified as permanent constraints on the GRID card.
6. The enforced displacement, D, is used only in static analyses (Rigid Formats 1, 2, 4, 5, 6, 14).
7. In heat transfer analysis, constraints applied to component number 1 are used to fix the temperature at that point.
8. D may be used to define an enforced temperature in static heat transfer analysis (Rigid Format 1 only). See Section 1.8 for methods of defining boundary temperatures in other Rigid Formats.

Input Data Card SPC1 Single-Point Constraint

Description: Defines sets of single-point constraints.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SPC1	SID	C	G1	G2	G3	G4	G5	G6	abc
SPC1	3	2	1	3	10	9	6	5	ABC

+bc	G7	G8	G9	-etc.-					
+BC	2	8							

Alternate Form

SPC1	SID	C	GID1	"THRU"	GID2	X	X	X	
SPC1	313	12456	6	THRU	32				

Field	Contents
SID	Identification number of single-point constraint set (Integer > 0)
C	Component number (Any unique combination of the digits 1-6 (with no imbedded blanks) when point identification numbers are grid points; zero or blank if point identification numbers are scalar points)
Gi, GIDi	Grid or scalar point identification numbers (Integer > 0)

Remarks:

1. Note that enforced displacements are not available via this card. As many continuation cards as desired may appear when "THRU" is not used.

2. A coordinate referenced on this card may not appear as a dependent coordinate in a multi point constraint relation (MPC) or as a degree of freedom on a rigid element (CRIGD1, CRIGD2, CRIGD3, CRIGDR), nor may it be referenced on a SPC, ØMIT, ØMIT1, or SUPØRT card.

3. Single-point constraint sets must be selected in the Case Control Deck (SPC=SID) to be used by NASTRAN.

4. SPC degrees of freedom may be redundantly specified as permanent constraints on the GRID card.

5. All grid points referenced by GID1 thru GID2 must exist.

6. In heat transfer analysis, constraints applied to component number 1 are used to fix the temperature at a point.

Input Data Card SPCADD Single-Point Constraint

Description: Defines a single-point constraint set as a union of single-point constraint sets defined via SPC or SPC1 cards.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SPCADD	SID	S1	S2	S3	S4	S5	S6	S7	abc
SPCADD	100	3	2	9	1				
+bc	S8	S9	-etc.-						

-etc.-

Field	Contents
SID	Identification number for new single-point constraint set (Integer > 0; ≠ 101 or 102 if axisymmetric)
Si	Identification numbers of single-point constraint sets defined via SPC or SPC1 cards (Integer > 0; SID ≠ Si)

Remarks:

1. Single-point constraint sets must be selected in the Case Control Deck (SPC=SID) to be used by NASTRAN.
2. No Si may be the identification number of a single-point constraint set defined by another SPCADD card.
3. The Si values must be unique.
4. Set identification numbers of 101 or 102 cannot be used in axisymmetric problems.

Input Data Card SPCAX Axisymmetric Single-Point Constraint

Description: Defines sets of single-point constraints for a model containing CCØNEAX, CTRAPAX or CTRIAAX elements.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SPCAX	SID	RID	HID	C	V				
SPCAX	2	3	4	13	6.0				

Field	Contents
SID	Identification number of single-point constraint set (Integer > 0; ≠ 101 or 102)
RID	Ring identification number (see RINGAX) (Integer ≥ 0)
HID	Harmonic identification number (Integer ≥ 0)
C	Component identification number (any unique combination of the digits 1-6)
V	Enforced displacement value (Real)

Remarks:
1. This card is allowed if and only if an AXIC card is also present.
2. Single-point constraint sets must be selected in the Case Control Deck (SPC=SID) to be used by NASTRAN.
3. Coordinates appearing on SPCAX cards may not appear on MPCAX, SUPAX or ØMITAX cards.
4. For a discussion of the conical shell problem, see Section 5.9 of the Theoretical Manual.
5. For a discussion of the axisymmetric solid problem, see Section 5.11 of the Theoretical Manual.

Input Data Card SPCD   Enforced Displacement Value

Description: Defines an enforced displacement value for static analysis, which is requested as a LØAD.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SPCD	SID	G	C	D	G	C	D		
SPCD	100	32	436	-2.6	5		+2.9		

Field	Contents
SID	Identification number of a static load set (Integer > 0)
G	Grid or scalar point identification number (Integer > 0)
C	Component number (any unique combination of the digits 1-6 (with no imbedded blanks) when point identification numbers are grid points; zero or blank if point identification numbers are scalar points)
D	Value of enforced displacement for all coordinates designated by G and C (Real)

Remarks:

1. A coordinate referenced on this card must be referenced by a selected SPC or SPC1 data card.
2. Values of D will override the values specified on an SPC bulk data card, if the LØAD set is requested.
3. The bulk data LØAD combination card will <u>not</u> request an SPCD.
4. At least one bulk data LØAD card (FØRCE, SLØAD, etc.) is required in the LØAD set selected in case control.
5. The enforced displacement, D, is used only in static analyses (Rigid Formats 1, 2, 4, 5, 6, 14).
6. In heat transfer analysis, D, is used to define an enforced temperature in statics analysis (Rigid Format 1 only). See Section 1.8 for methods of defining boundary temperatures in other Rigid Formats.

Input Data Card SPCFLD - Specified Magnetic Field

Description: Specifies magnetic field at selected grid points.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SPCFLD	SID	CID	HCX	HCY	HCZ	G1	G2	G3	
SPCFLD	18		12.25	0.	62.	8	17	103	

First Alternate Form:

SPCFLD	SID	CID	HCX	HCY	HCZ	GID1	"THRU"	GID2	
SPCFLD	18		12.25	0.	62.	9	THRU	27	

Second Alternate Form:

SPCFLD	SID	CID	HCX	HCY	HCZ	-1			
SPCFLD	18		12.25	0.	62.	-1			

Field	Contents
SID	Load set identification number (Integer > 0)
CID	Coordinate system identification number (Integer > 0 or blank)
HCX,HCY,HCZ	Components of specified H_c field in coordinate system CID (Real)
Gi,GIDi	Grid point identification numbers (Integer > 0)

Remarks:

1. Load sets must be selected in the Case Control Deck (LØAD=SID) to be used by NASTRAN.
2. If the first alternate form of the card is used, all grid point identification numbers between GID1 and GID2 must exist.
3. The second alternate form of the card implies that the specified H_c field applies to all grid points.
3. CID must presently be 0 or blank.

Input Data Card SPCS Substructure Single Point Constraints

Description: Defines a set of single point constraints on a specified basic substructure.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SPCS	SID	NAME	G1	C1	G2	C2	G3	C3	abc
SPCS	61	MIDWG	9	45	18	124	36	456	ABC

+bc	G4	C4	G5	C5	G6	C6	G7	C7	def
+BC	88	136	etc.						

Field	Contents
SID	Set identification number (Integer > 0)
NAME	Basic substructure name (BCD)
Gi	Grid or scalar point identification number in substructure (Integer > 0)
Ci	Component number - Any unique combination of the digits 1 - 6 (with no imbedded blanks) when the Gi are grid points, or null if they are scalar points.

Remarks:

1. A coordinate referenced on this card may not appear as a dependent coordinate in a multipoint constraint relation, nor may it be referenced on a SPCS1, SPC, SPC1, ØMIT, ØMIT1 or SUPØRT card.
2. Single-point forces of constraint are recovered during stress data recovery.
3. Single-point constraint sets must be selected in the Case Control Deck (SPC=SID) to be used by NASTRAN.
4. A single G, C pair may not specify all component degrees of freedom for a connected grid point where only some of the degrees of freedom of the grid point have been connected or when some have been disconnected via the RELES card. The degrees of freedom which were connected and those that were not connected must be referenced separately.

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Input Data Card SPCS1 Substructure Single Point Constraints

Description: Defines a set of single point constraints on a specified basic substructure.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SPCS1	SID	NAME	C	G1	G2	G3	G4	G5	abc
SPCS1	15	FUSELAGE	1236	1101	1102	1105	THRU	1110	ABC
+bc	G6	G7	G8	G9	G10	G11	G12	G13	def
+BC	1121	1130	THRU	1140	1143	1150	etc.		

Field	Contents
SID	Set identification number (Integer > 0)
NAME	Basic substructure name (BCD)
C	Component number - Any unique combination of the digits 1 - 6 (with no imbedded blanks) when the Gi are grid points, or null if they are scalar points
Gi	Grid or scalar point identification numbers (Integer > 0)

Remarks: 1. THRU may appear in fields 6, 7, or 8 of the first card and anywhere in fields 3 - 8 on a continuation card.

2. A coordinate referenced on this card may not appear as a dependent coordinate in a multipoint constraint relation, nor may it be referenced on a SPCS1, SPC, SPC1, ØMIT, ØMIT1 or SUPØRT card.

3. Single-point constraint sets must be selected in the Case Control Deck (SPC=SID) to be used by NASTRAN.

4. All grid points referenced by Gi through Gj must exist.

5. A single G, C pair may not specify all component degrees of freedom for a connected grid point where only some of the degrees of freedom of the grid point have been connected or when some have been disconnected via the RELES card. The degrees of freedom which were connected and those that were not connected must be referenced separately.

Input Data Card SPCSD   Substructure Enforced Displacement Values

Description: Defines enforced displacement values for a given substructure during static analysis, which are requested as a LØAD.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SPCSD	SID	NAME	G1	C1	D1	G2	C2	D2	
SPCSD	27	LWINGRT	965	3	3.6				

Field	Contents
SID	Identification number of a static load set (Integer > 0)
NAME	Basic substructure name (BCD)
Gi	Grid or scalar point identification number (Integer > 0)
Ci	Component number - Any unique combination of the digits 1 - 6 (with no imbedded blanks) when the Gi are grid points, or null if they are scalar points.
Di	Value of enforced displacement for all coordinates designated by Gi and Ci (Real)

Remarks:
1. A coordinate referenced on this card must be referenced by a selected SPCS or SPCS1 data card.
2. The bulk data LØAD combination card will not request an SPCSD.
3. At least one bulk data load card (LØADC or SLØAD) in addition to the SPCSD cards is required in the LØAD set selected in case control (LØAD = SID).

Input Data Card SPLINE1 Surface Spline

Description: Defines a surface spline for interpolating out-of-plane motion for aeroelastic problems.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SPLINE1	EID	CAERØ	BØX1	BØX2	SETG	DZ			
SPLINE1	3	111	111	118	14	0.			

Field Contents

EID Element identification number (unique Integer > 0).

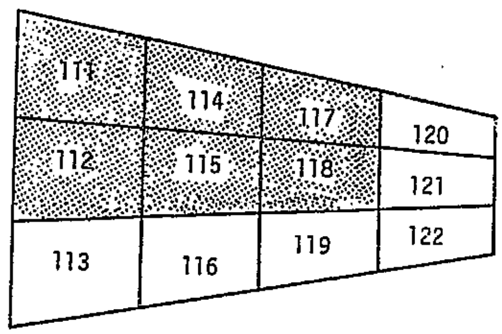
CAERØ Aero element ID which defines plane of spline (Integer > 0).

BØX1,BØX2 First and last box whose motions are interpolated using this spline (Integer > 0).

SETG Refers to a SETi card which lists the structural grid points to which the spline is attached (Integer > 0).

DZ Linear attachment flexibility (Real ≥ 0).

Remarks: 1. The interpolated points (k-set) will be defined by aero-cells. The sketch shows the cells for which u_k is interpolated if BØX1 = 111 and BØX2 = 118.



2. The attachment flexibility (units of area) is used for smoothing the interpolation. If DZ = 0, the spline will pass thru all deflected grid points. If DZ >> (area of spline, a least squares plane fit will occur. Intermediate values will provide smoothing.

NASTRAN DATA DECK

Input Data Card SPLINE2 Linear Spline

Description: Defines a beam spline for interpolating panels and bodies for aeroelastic problems.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SPLINE2	EID	CAERØ	ID1	ID2	SETG	DZ	DTØR	CID	ABC
SPLINE2	5	8	12	24	60	0.	1.0	3	abc
+BC	DTHX	DTHY							
+bc	-1.								

Field Contents

EID Element identification number (Integer > 0).

CAERØ Aero panel or body which is to be interpolated (Integer > 0).

ID1, ID2 First and last box or body element whose motions are interpolated using this spline (Integer > 0).

SETG Refers to a SETi card which lists the structural "g"-set to which the spline is attached (Integer > 0).

DZ Linear attachment flexibility (Real ≥ 0).

DTØR Torsional flexibility (EI/GJ) (Real > 0; use 1.0 for bodies).

CID Rectangular coordinate system which defines y-axis of spline (Integer ≥ 0) (not used for bodies, CAERØ2).

DTHX, DTHY Rotational attachment flexibility. DTHX is for rotation about the x-axis; not used for bodies. DTHY is for rotation about the y-axis; used for slope of bodies (Real).

Remarks:
1. The interpolated points (k-set) will be defined by aero boxes.
2. For panels, the spline axis is the projection of the y-axis of coordinate system CID, projected onto the plane of the panel. For bodies, the spline axis is parallel to the x-axis of the aerodynamic coordinate system.
3. The flexibilities are used for smoothing. Zero attachment flexibility values will imply rigid attachment, i.e., no smoothing. (Negative values in fields 12 and 13 will imply infinity, hence no attachment.)
4. A continuation card is required.
5. The SPLINE2 EID must be unique with respect to all SPLINEi data cards.

Input Data Card SPLINE3

Description: Defines a constraint equation for aeroelastic problems. Useful for control surface constraints.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SPLINE3	EID	CAERØ	UKID	CØMP	G1	C1	A1		ABC
SPLINE3	7000	107	109	6	33	5	1.0		abc
+BC	G2	C2	A2		G3	C3	A3		
+bc	43	5	-1.0						

-- etc. --

Field	Contents
EID	Element identification number (Integer > 0).
CAERØ	Identification number of macro-element on which the element to be interpolated lies (Integer > 0).
UKID	Identification number of the u_k point (i.e., the box number)(Integer > 0).
CØMP	The component of motion to be interpolated. 3 = normal rotation, 5 = pitch angle (for z, yz bodies), 6 = control relative angle (also for y-bodies 2 = lateral displacement and 6 = yaw). (Integer > 0)
Gi	Grid point identification number of independent grid point (Integer > 0).
Ci	Component (in global coordinate system) to be used (one of the Integers 1 thru 6, or 0 for scalar points).
Ai	Coefficient of constraint relationship (Real).

Remarks:

1. The independent grid points and components must refer to degrees of freedom in the u_g point set.

2. The constraint is given by

$$u_d = \sum_i A_i u_i$$

u_d = the value of the dependent u_k component.

u_i = the displacement at grid Gi, component Ci.

3. The SPLINE3 EID must be unique with respect to all SPLINEi data cards.

Input Data Card SPØINT Scalar Point

Description: Defines scalar points of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SPØINT	ID	ID	ID	ID	ID	ID	ID	ID	
SPØINT	3	18	1	4	16	2			

Alternate Form

1	2	3	4	5	6	7	8	9	10
SPØINT	ID1	"THRU"	ID2						
SPØINT	5	THRU	649						

Field	Contents
ID,ID1,ID2	Scalar point identification number (Integer > 0; ID1 < ID2)

Remarks:
1. Scalar point defined by their appearance on a scalar connection card need not appear on a SPØINT card.
2. All scalar point identification numbers must be unique with respect to all other structural, scalar, and fluid points.
3. This card is used primarily to define scalar points appearing in single or multipoint constraint equations but to which no scalar elements are connected.
4. If the alternate form is used, scalar points ID1 thru ID2 are defined.
5. For a discussion of scalar points, see Section 5.6 of the Theoretical Manual.

Input Data Card SUPAX Axisymmetric Fictitious Support

Description: Defines coordinates at which the user desires determinate reactions to be applied during the analysis of a free body modeled with CCØNEAX, CTRAPAX or CTRIAAX elements.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SUPAX	RID	HID	C	RID	HID	C			
SUPAX				4	3	2			

Field	Contents
RID	Ring identification number (Integer > 0)
HID	Harmonic identification number (Integer ≥ 0)
C	Component number (any unique combination of the digits 1-6)

Remarks:
1. This card is allowed if and only if an AXIC card is also present.
2. Up to 12 coordinates may appear on a single card.
3. Coordinates appearing on SUPAX cards may not appear on MPCAX, SPCAX or ØMITAX cards.
4. For a discussion of the conical shell problem, see Section 5.9 of the Theoretical Manual.
5. For a discussion of the axisymmetric solid problem, see Section 5.11 of the Theoretical Manual.

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Input Data Card SUPØRT Fictitious Support

Description: Defines coordinates at which the user desires determinate reactions to be applied to a free body during analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SUPØRT	ID	C	ID	C	ID	C	ID	C	
SUPØRT	16	215							

Field	Contents
ID	Grid or scalar point identification number (Integer > 0)
C	Component number (Zero or blank for scalar points; any unique combination of the digits 1-6 for grid points)

Remarks: 1. Coordinates defined on this card may not appear on single-point constraint cards (SPC, SPC1), on omit cards (ØMIT, ØMIT1) or as dependent coordinates in multipoint constraint equations (MPC) or as degrees of freedom on rigid elements (CRIGD1, CRIGD2, CRIGD3, CRIGDR).

2. From one to twenty-four support coordinates may be defined on a single card.

Input Data Card TABDMP1 Structural Damping Table

Description: Defines structural damping as a tabular function of frequency.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TABDMP1	ID								abc
TABDMP1	3								ABC
+bc	F_1	G_1	F_2	G_2	F_3	G_3	F_4	G_4	
+BC	2.5	.01057	2.6	.01362	ENDT				

Field	Contents
ID	Table identification number (Integer > 0)
F_i	Frequency value in cycles per unit time (Real $\geq$ 0.0)
G_i	Damping value (Real)

Remarks:
1. The F_i must be in either ascending or descending order but not both.
2. Jumps ($F_i = F_{i+1}$) are allowed, but not at the end points.
3. At least two entries must be present.
4. Any F_i, G_i entry may be ignored by placing the BCD string "SKIP" in either of two fields used for that entry.
5. The end of the table is indicated by the existence of the BCD string "ENDT" in either of the two fields following the last entry. An error is detected if any continuation cards follow the card containing the end-of-table flag "ENDT".
6. The TABDMP1 mnemonic infers the use of the algorithm

$$\boxed{G = g_T(F)}$$

where F is input to the table and G is returned. The table look-up $g_T(F)$ is performed using linear interpolation within the table and linear extrapolation outside the table using the last two end points at the appropriate table end. At jump points the average $g_T(F)$ is used. There are no error returns from this table look-up procedure.

7. Structural damping tables must be selected in the Case Control Deck (SDAMP=ID) to be used by NASTRAN.
8. Structural damping is used only in modal formulations of complex eigenvalue analysis, frequency response analysis, or transient response analysis.
9. A PARAM, KDAMP, is used in Aeroelastic rigid formats to select the type of damping. See PARAM bulk data card.

Input Data Card TABLED1 Dynamic Load Tabular Function

Description: Defines a tabular function for use in generating frequency-dependent and time-dependent dynamic loads.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TABLED1	ID								+abc
TABLED1	32								ABC
+abc	X_1	Y_1	X_2	Y_2	X_3	Y_3	X_4	Y_4	
+BC	-3.0	6.9	2.0	5.6	3.0	5.6	ENDT		.

Field	Contents
ID	Table identification number (Integer > 0)
X_i, Y_i	Tabular entries (Real)

Remarks:

1. The X_i must be in either ascending or decending order but not both.
2. Jumps between two points ($X_i = X_{i+1}$) are allowed, but not at the end points.
3. At least two entries must be present.
4. Any X-Y entry may be ignored by placing the BCD string "SKIP" in either of the two fields used for that entry.
5. The end of the table is indicated by the existence of the BCD string "ENDT" in either of the two fields following the last entry. An error is detected if any continuation cards follow the card containing the end-of-table flag "ENDT".
6. Each TABLEDi mnemonic infers the use of a specific algorithm. For TABLED1 type tables, this algorithm is

$$\boxed{Y = y_T(X)}$$

where X is input to the table and Y is returned. The table look-up $y_T(x)$, $x = X$, is performed using linear interpolation within the table and linear extrapolation outside the table using the last two end points at the appropriate table end. At jump points the average $y_T(x)$ is used. There are no error returns from this table look-up procedure.

7. Linear extrapolation is not used for Fourier Transform methods. The function is zero outside the range.

Input Data Card TABLED2 Dynamic Load Tabular Function

Description: Defines a tabular function for use in generating frequency-dependent and time-dependent dynamic loads. Also contains parametric data for use with the table.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TABLED2	ID	X1							+abc
TABLED2	15	-10.5							ABC
+abc	X_1	Y_1	X_2	Y_2	X_3	Y_3	X_4	Y_4	+def
+BC	1.0	-4.5	2.0	-4.2	2.0	2.8	7.0	6.5	DEF
+def	X_5	Y_5	X_6	Y_6	X_7	Y_7	X_8	Y_8	
+EF	SKIP	SKIP	9.0	6.5	ENDT				

Field	Contents
ID	Table identification number (Integer > 0)
X1	Table parameter (Real)
X_i, Y_i	Tabular entries (Real)

Remarks: 1. The X_i must be in either ascending or descending order but not both.

2. Jumps between two points ($X_i = X_{i+1}$) are allowed, but not at the end points.

3. At least two entries must be present.

4. Any X-Y entry may be ignored by placing the BCD string "SKIP" in either of the two fields used for that entry.

5. The end of the table is indicated by the existence of the BCD string "ENDT" in either of the two fields following the last entry. An error is detected if any continuation cards follow the card containing the end-of-table flag "ENDT".

6. Each TABLEDi mnemonic infers the use of a specific algorithm. For TABLED2 type tables, this algorithm is

$$\boxed{Y = y_T(X - X1)}$$

where X is input to the table and Y is returned. The table look-up $y_T(x)$, $x = X - X1$, is performed using linear interpolation within the table and linear extrapolation outside the table using the last two end points at the appropriate table end. At jump points the average $y_T(x)$ is used. There are no error returns from this table look-up procedure.

7. Linear extrapolation is not used for Fourier Transform methods. The function is zero outside the range.

Input Data Card TABLED3 Dynamic Load Tabular Function

Description: Defines a tabular function for use in generating frequency-dependent and time-dependent dynamic loads. Also contains parametric data for use with the table.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TABLED3	ID	X1	X2						+abc
TABLED3	62	126.9	30.0						ABC
+abc	X_1	Y_1	X_2	Y_2	X_3	Y_3	X_4	Y_4	
+BC	2.9	2.9	3.6	4.7	5.2	5.7	ENDT		

Field	Contents
ID	Table identification number (Integer > 0)
X1, X2	Table parameters (Real; X2 $\neq$ 0.0)
X_i, Y_i	Tabular entries (Real)

Remarks:

1. The X_i must be in either ascending or descending order but not both.
2. Jumps between two points ($X_i = X_{i+1}$) are allowed, but not at the end points.
3. At least two entries must be present.
4. Any X-Y entry may be ignored by placing the BCD string "SKIP" in either of the two fields used for that entry.
5. The end of the table is indicated by the existence of the BCD string "ENDT" in either of the two fields following the last entry. An error is detected if any continuation cards follow the card containing the end-of-table flag "ENDT".
6. Each TABLEDi mnemonic infers the use of a specific algorithm. For TABLED3 type tables, this algorithm is

$$\boxed{Y = y_T\left(\frac{X - X1}{X2}\right)}$$

where X is input to the table and Y is returned. The table look-up $y_T(x)$, $x = \frac{X - X1}{X2}$, is performed using linear interpolation within the table and linear extrapolation outside the table using the last two end points at the appropriate table end. At jump points the average $y_T(x)$ is used. There are no error returns from this table look-up procedure.

7. Linear extrapolation is not used for Fourier Transform methods. The function is zero outside the range.

Input Data Card TABLED4 Dynamic Load Tabular Function

Description: Defines coefficients of a power series for use in generating frequency-dependent and time-dependent dynamic loads. Also contains parametric data for use with the table.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TABLED4	ID	X1	X2	X3	X4				+abc
TABLED4	28	0.0	1.0	0.0	100.				ABC
+abc	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7	+def
+BC	2.91	-0.0329	6.51-5	0.0	-3.4-7	ENDT			

etc.

Field	Contents
ID	Table identification number (Integer > 0)
X1,X2,X3,X4	Table parameters (Real; X2 $\neq$ 0.0; X3 < X4)
A_i	Coefficient entries (Real)

Remarks: 1. At least one entry must be present.

2. The end of the table is indicated by the existence of the BCD string "ENDT" in the field following the last entry. An error is detected if any continuation cards follow the card containing the end-of-table flag "ENDT".

3. Each TABLEDi mnemonic infers the use of a specific algorithm. For TABLED4 type tables, this algorithm is

$$\boxed{Y = \sum_{i=0}^{N} A_i \left(\frac{X - X1}{X2}\right)^i}$$

where X is input to the table and Y is returned. Whenever X < X3, use X3 for X; whenever X > X4, use X4 for X. There are N + 1 entries in the table. There are no error returns from this table look-up procedure.

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Input Data Card TABLEM1 Material Property Table

Description: Defines a tabular function for use in generating temperature dependent material properties.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TABLEM1	ID								+abc
TABLEM1	32								ABC
+abc	x_1	y_1	x_2	y_2	x_3	y_3	x_4	y_4	+def
+BC	-3.0	6.9	2.0	5.6	3.0	5.6	ENDT		

(etc.)

Field	Contents
ID	Table identification number (Integer > 0)
x_i, y_i	Tabular entries (Real)

Remarks:

1. The x_i must be in either ascending or descending order but not both.
2. Jumps between two points ($x_i = x_{i+1}$) are allowed, but not at the end points.
3. At least two entries must be present.
4. Any x-y entry may be ignored by placing the BCD string "SKIP" in either of the two fields used for that entry.
5. The end of the table is indicated by the existence of the BCD string "ENDT" in either of the two fields following the last entry. An error is detected if any continuation cards follow the card containing the end-of-table flag "ENDT".
6. Each TABLEMi mnemonic infers the use of a specific algorithm. For TABLEM1 type tables, this algorithm is

$$\boxed{Y = y_T(X)}$$

where X is input to the table and Y is returned. The table look-up $y_T(x)$, $x = X$, is performed using linear interpolation within the table and linear extrapolation outside the table using the last two end points at the appropriate table end. At jump points the average $y_T(x)$ is used. There are no error returns from this table look-up procedure.

Input Data Card TABLEM2 Material Property Table

Description: Defines a tabular function for use in generating temperature dependent material properties. Also contains parametric data for use with the table.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TABLEM2	ID	X1							+abc
TABLEM2	15	-10.5							ABC
+abc	x_1	y_1	x_2	y_2	x_3	y_3	x_4	y_4	+def
+BC	1.0	-4.5	2.0	-4.5	2.0	2.8	7.0	6.5	DEF
+def	x_5	y_5	x_6	y_6	x_7	y_7	x_8	y_8	+ghi
+EF	SKIP	SKIP	9.0	6.5	ENDT				

(etc.)

Field	Contents
ID	Table identification number (Integer > 0)
X1	Table parameter (Real)
x_i, y_i	Tabular entries (Real)

Remarks:

1. The x_i must be in either ascending or descending order but not both.
2. Jumps between two points ($x_i = x_{i+1}$) are allowed, but not at the end points.
3. At least two entries must be present.
4. Any x-y entry may be ignored by placing the BCD string "SKIP" in either of the two fields used for that entry.
5. The end of the table is indicated by the existence of the BCD string "ENDT" in either of the two fields following the last entry. An error is detected if any continuation cards follow the card containing the end-of-table flag "ENDT".
6. Each TABLEMi mnemonic infers the use of a specific algorithm. For TABLEM2 type tables, this algorithm is

$$\boxed{Y = Z\, y_T(X - X1)}$$

where X is input to the table, Y is returned and Z is supplied from the basic MATi card. The table look-up $y_T(x)$, $x = X - X1$, is performed using linear interpolation within the table and linear extrapolation outside the table using the last two end points at the appropriate table end. At jump points the average $y_T(x)$ is used. There are no error returns from this table look-up procedure.

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Input Data Card TABLEM3 Material Property Table

Description: Defines a tabular function for use in generating temperature dependent material properties. Also contains parametric data for use with the table.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TABLEM3	ID	X1	X2						+abc
TABLEM3	62	126.9	30.0						ABC
+abc	x_1	y_1	x_2	y_2	x_3	y_3	x_4	y_4	+def
+BC	2.9	2.9	3.6	4.7	5.2	5.7	ENDT		

(etc.)

Field	Contents
ID	Table identification number (Integer > 0)
X1, X2	Table parameters (Real; X2 ≠ 0.0)
x_i, y_i	Tabular entries (Real)

Remarks: 1. The x_i must be in either ascending or descending order but not both.

2. Jumps between two points ($x_i = x_{i+1}$) are allowed, but not at the end points.

3. At least two entries must be present.

4. Any x-y entry may be ignored by placing the BCD string "SKIP" in either of the two fields used for that entry.

5. The end of the table is indicated by the existence of the BCD string "ENDT" in either of the two fields following the last entry. An error is detected if any continuation cards follow the card containing the end-of-table flag "ENDT".

6. Each TABLEMi mnemonic infers the use of a specific algorithm. For TABLEM3 type tables, this algorithm is

$$\boxed{Y = Z\, y_T\left(\frac{X - X1}{X2}\right)}$$

where X is input to the table, Y is returned and Z is supplied from basic MATi card. The table look-up $y_T(x)$, $x = \frac{X - X1}{X2}$, is performed using linear interpolation within the table and linear extrapolation outside the table using the last two end points at the appropriate table end. At jump points the average $y_T(x)$ is used. There are no error returns from this table look-up procedure.

Input Data Card TABLEM4 Material Property Table

Description: Defines coefficients of a power series for use in generating temperature dependent material properties. Also contains parametric data for use with the table.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TABLEM4	ID	X1	X2	X3	X4				+abc
TABLEM4	28	0.0	1.0	0.0	100.				ABC
+abc	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7	+def
+BC	2.91	-0.0329	6.51-5	0.0	-3.4-7	ENDT			

etc.

Field	Contents
ID	Table identification number (Integer > 0)
X1,X2,X3,X4	Table parameters (Real; X2 $\neq$ 0.0; X3 < X4)
A_i	Coefficient entries (Real)

Remarks:
1. At least one entry must be present.
2. The end of the table is indicated by the existence of the BCD string "ENDT" in the field following the last entry. An error is detected if any continuation cards follow the card containing the end-of-table flag "ENDT".
3. Each TABLEMi mnemonic infers the use of a specific algorithm. For TABLEM4 type tables, this algorithm is

$$\boxed{Y = Z \sum_{i=0}^{N} A_i \left(\frac{X - X1}{X2}\right)^i}$$

where X is input to the table, Y is returned and Z is supplied from the basic MATi card. Whenever X < X3, use X3 for X; whenever X > X4, use X4 for X. There are N +1 entries in the table. There are no error returns from this table look-up procedure.

Input Data Card TABLES1 Tabular Stress-Strain Function

Description: Defines a tabular stress-strain function for use in Piecewise Linear Analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TABLES1	ID								+abc
TABLES1	32								ABC
+abc	x_1	y_1	x_2	y_2	x_3	y_3	x_4	y_4	+def
+BC	-3.0	6.9	2.0	5.6	3.0	5.6	ENDT		

-etc.-

Field	Contents
ID	Table identification number (Integer > 0)
x_i, y_i	Tabular entries (Real)

Remarks:

1. The x_i must be in either ascending or descending order but not both.
2. For Piecewise Linear Analysis, the y_i numbers must form a nondecreasing sequence for an ascending x_i sequence and vice versa.
3. Jumps between two points ($x_i = x_{i+1}$) are allowed, but not at the end points.
4. At least two entries must be present.
5. Any x-y entry may be ignored by placing the BCD string "SKIP" in either of the two fields used for that entry.
6. The end of the table is indicated by the existence of the BCD string "ENDT" in either of the two fields following the last entry. An error is detected if any continuation cards follow the card containing the end-of-table flag "ENDT".
7. Each TABLESi mnemonic infers the use of a specific algorithm. For TABLES1 type tables, this algorithm is

$$\boxed{Y = y_T(X)}$$

where X is input to the table and Y is returned. The table look-up $y_T(x)$, $x = X$, is performed using linear interpolation within the table and linear extrapolation outside the table using the last two end points at the appropriate table end. At jump points the average $y_T(x)$ is used. There are no error returns from this table look-up procedure.

8. The table may have a zero slope only at its end.

Input Data Card TABRND1 Power Spectral Density Table

Description: Defines Power Spectral density as a tabular function of frequency for use in Random Analysis. Referenced on the RANDPS card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TABRND1	ID								abc
TABRND1	3								ABC
+bc	f_1	g_1	f_2	g_2	f_3	g_3	f_4	g_4	def
+BC	2.5	.01057	2.6	.01362	ENDT				

-etc.-

Field	Contents
ID	Table identification number (Integer > 0)
f_i	Frequency value in cycles per unit time (Real ≥ 0.0)
g_i	Power Spectral Density (Real)

Remarks:

1. The f_i must be in either ascending or descending order but not both.
2. Jumps between two points ($f_i = f_{i+1}$) are allowed, but not at the end points.
3. At least two entries must be present.
4. Any f-g entry may be ignored by placing the BCD string "SKIP" in either of the two fields used for that entry.
5. The end of the table is indicated by the existence of the BCD string "ENDT" in either of the two fields following the last entry. An error is detected if any continuation cards follow the card containing the end-of-table flag "ENDT".
6. The TABRND1 mnemonic infers the use of the algorithm

$$\boxed{G = g_T(F)}$$

where F is input to the table and G is returned. The table look-up $g_T(F)$ is performed using linear interpolation within the table and linear extrapolation outside the table using the last two end points at the appropriate table end. At jump points the average $g_T(F)$ is used. There are no error returns from this table look-up procedure.

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NASTRAN DATA DECK

Input Data Card TABRNDG Gust Power Spectral Density

Description: Defines the power spectral density of a gust for Aeroelastic analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TABRNDG	ID	TYPE	LU	WG					
TABRNDG	1020	1	1.3	1.					

Field — Contents

ID Table identification number (Integer > 0).

TYPE Choice of Von Kármán (TYPE=1) or Dryden model (TYPE=2) (Integer 1 or 2).

LU L/U, scale of turbulence divided by velocity (units of time) (Real).

WG Root-mean-square gust velocity.

Remarks: 1. This card must be referenced on a RANDPS data card.

2. The power spectral density is given by:

$$S_q(\omega) = 2(WG)^2(L/U)\frac{1+2(p+1)k^2(L/U)^2\omega^2}{[1+k^2(L/U)^2\omega^2]^{p+3/2}}$$

where

Type	p	k
1=Von Karman	1/3	1.339
2=Dryden	1/2	1.0

and $\omega = 2\pi f$. The units of $S_q(\omega)$ are velocity squared per Hertz.

3. Cther PSD functions may be defined using the TABRND1 data card.

Input Data Card TEMP   Grid Point Temperature Field

Description: Defines temperature at grid points for determination of:

1) Thermal loading
2) Temperature-dependent material properties
3) Stress recovery

Format and Example:

1	2	3	4	5	6	7	8	9	10
TEMP	SID	G	T	G	T	G	T		
TEMP	3	94	316.2	49	219.8				

Field	Contents
SID	Temperature set identification number (Integer > 0)
G	Grid point identification number (Integer > 0)
T	Temperature (Real)

Remarks:

1. Temperature sets must be selected in the Case Control Deck (TEMP=SID) to be used by NASTRAN.

2. From one to three grid point temperatures may be defined on a single card.

3. If thermal effects are requested, all elements must have a temperature field defined either directly on a TEMPP1, TEMPP2, TEMPP3, or TEMPRB card or indirectly as the average of the connected grid point temperatures defined on the TEMP or TEMPD cards. Directly defined element temperatures always take precedence over the average of grid point temperatures.

4. If the element material is temperature dependent, its properties are evaluated at the average temperature. In the case of isoparametric hexahedron elements, their properties are evaluated at the temperature computed by interpolating the grid point temperatures.

5. Average element temperatures are obtained as a simple average of the connecting grid point temperatures when no element temperature data are defined.

6. Set ID must be unique with respect to all other LØAD type cards if TEMP(LØAD) is specified in Case Control Deck.

7. In heat transfer analysis, the TEMP card is used for the following special purposes:

   a) The Case Control card, TEMP(MATERIAL), will select the initial estimated temperature field for nonlinear conductivity and radiation effects. See Section 1.8.

   b) Boundary temperatures are defined in Rigid Format 3, HEAT by the Case Control card, TEMP(MATERIAL). These points are specified with SPC cards.

   c) The Case Control card, IC, will select the initial conditions, i.e., grid point temperatures, in transient analysis.

Input Data Card TEMPAX Axisymmetric Temperature

Description: Defines temperature sets for a model containing CCØNEAX, CTRAPAX or CTRIAAX elements.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TEMPAX	SID	RID	PHI	TEMP	SID	RID	PHI	TEMP	
TEMPAX	4	7	30.0	105.3					

Field	Contents
SID	Temperature set identification number (Integer > 0)
RID	Ring identification number (see RINGAX card) (Integer > 0)
PHI	Azimuthal angle in degrees (Real)
TEMP	Temperature (Real)

Remarks:

1. This card is allowed if and only if an AXIC card is also present.
2. One or two temperatures may be defined on each card.
3. Temperature sets must be selected in the case Control Deck (TEMP=SID) to be used by NASTRAN.
4. Set ID must be unique with respect to all other LØAD type cards if TEMP(LØAD) is specified in Case Control Deck.
5. At least two different angles are required for each RID and temperature set to specify the subtended angle $[\phi_b - \phi_a]$ over which the temperature applies.
6. For a discussion of the conical shell problem, see Section 5.9 of the Theoretical Manual.
7. For a discussion of the axisymmetric solid problem, see Section 5.11 of the Theoretical Manual.

Input Data Card TEMPD Grid Point Temperature Field Default

Description: Defines a temperature default for all grid points of the structural model which have not been given a temperature on a TEMP card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TEMPD	SID	T	SID	T	SID	T	SID	T	
TEMPD	1	216.3							

Field	Contents
SID	Temperature set identification number (Integer > 0)
T	Default temperature (Real)

Remarks:

1. Temperature sets must be selected in the Case Control Deck (TEMP=SID) to be used by NASTRAN.
2. From one to four default temperatures may be defined on a single card.
3. If thermal effects are requested, all elements must have a temperature field defined either directly on a TEMPP1, TEMPP2, TEMPP3, or TEMPRB card or indirectly as the average of the connected grid point temperatures defined on the TEMP or TEMPD cards. Directly defined element temperatures always take precedence over the average of grid point temperatures.
4. If the element material is temperature dependent its properties are evaluated at the average temperature. In the case of isoparametric hexahedron elements, their properties are evaluated at the temperature computed by interpolating the grid point temperatures.
5. Average element temperatures are obtained as a simple average of the connecting grid point temperatures when no element temperature data are defined.
6. Set ID must be unique with respect to all other LØAD type cards if TEMP(LØAD) is specified in Case Control Deck.
7. In heat transfer analysis, the TEMP card is used for the following special purposes:
   a) The Case Control card, TEMP(MATERIAL), will select the initial estimated temperature field for nonlinear conductivity and radiation effects. See Section 1.8.
   b) Boundary temperatures are defined in Rigid Format 3, HEAT, by the Case Control card, TEMP(MATERIAL). These points are specified with SPC cards.
   c) The Case Control card, IC, will select the initial conditions, i.e., grid point temperatures, in transient analysis.

Input Data Card TEMPP1 Plate Element Temperature Field

Description: Defines a temperature field for plate, membrane and combination elements (by an average temperature and a thermal gradient over the cross-section) for determination of:

1) Thermal loading
2) Temperature-dependent material properties
3) Stress recovery

Format and Example:

1	2	3	4	5	6	7	8	9	10
TEMPP1	SID	EID1	$\bar{T}$	T'	T1	T2			+abc
TEMPP1	2	24	62.0	10.0	57.0	67.0			A1A
+abc	EID2	EID3	EID4	EID5	EID6	EID7	EID8	EID9	+def
+1A	26	21	19	30					

-etc.-

Alternate Form of Continuation Card

+abc	EID2	"THRU"	EIDi	EIDj	"THRU"	EIDk			+def
+1A	1	THRU	10	30	THRU	61			

-etc.-

Field	Contents
SID	Temperature set identification number (Integer > 0)
EIDn	Unique element identification number(s) (Integer > 0 or BCD: the continuation card may have THRU in fields 3 and/or 6, in which case EID2 < EIDi, EIDj < EIDk)
$\bar{T}$	Average temperature over the cross-section. Assumed constant over area (Real)
T'	Effective linear thermal gradient. Not used for membranes (Real)
T1, T2	Temperatures for stress calculation at points defined on the element property card. (Z1 and Z2 are given on PTRBSC, PQDPLT, PTRPLT, PTRIA1, and PQUAD1 cards. T1 may be specified on the lower surface and T2 on the upper surface for the QUAD2 and TRIA2 elements. These data are not used for membrane elements (Real)

Remarks:

1. Temperature sets must be selected in the Case Control Deck (TEMP=SID) to be used by NASTRAN.
2. If continuation cards are present, EID1 and elements specified on the continuation card(s) are used. Elements must not be specified more than once.
3. If thermal effects are requested, all elements must have a temperature field defined either directly on a TEMPP1, TEMPP2, TEMPP3, or TEMPRB card or indirectly as the average of the connected grid point temperatures defined on the TEMP or TEMPD cards. Directly defined element temperatures always take precedence over the average of grid point temperatures.
4. For a temperature field other than a constant gradient the "effective gradient" for a homogeneous plate is:

$$T' = \frac{1}{I} \int_z T(z) z \, dz$$

where I is the bending inertia, and z is the distance from the neutral surface in the positive normal direction.

(Continued)

TEMPP1 (Cont.)

5. The "average" temperature for a homogeneous plate is

$$\bar{T} = \frac{1}{\text{Volume}} \int_{\text{Volume}} T \, d\text{Volume}$$

6. If the element material is temperature dependent, its properties are evaluated at the average temperature $\bar{T}$.

7. Set ID must be unique with respect to all other LØAD type cards if TEMP(LØAD) is specified in Case Control Deck.

NASTRAN DATA DECK

Input Data Card TEMPP2 Plate Element Temperature Field

Description: Defines a temperature field for plate, membrane, and combination elements by an average temperature and thermal moments for determination of:

1) Thermal loading
2) Temperature-dependent material properties
3) Stress recovery

Format and Example:

1	2	3	4	5	6	7	8	9	10
TEMPP2	SID	EID1	$\bar{T}$	MX	MY	MXY	T1	T2	+abc
TEMPP2	2	36	68.8						XYZ
+abc	EID2	EID3	EID4	EID5	EID6	EID7	EID8	EID9	+def
+YZ	400	1	2	5					

-etc.-

Alternate Form of Continuation Card

+abc	EID2	"THRU"	EIDi	EIDj	"THRU"	EIDk			+def
+YZ	37	THRU	312	315	THRU	320			

-etc.-

Field	Contents
SID	Temperature set identification number (Integer > 0)
EIDn	Unique element identification number(s) (Integer > 0 or BCD: a continuation card may have THRU in field 3 and/or 6 in which case EID2 < EIDi, EIDj < EIDk)
$\bar{T}$	Average temperature over cross-section. Assumed constant over area (Real)
MX, MY, MXY	Resultant thermal moments per unit width in element coordinate system. Not used for membrane elements (Real)
T1, T2	Temperature for stress calculation at points defined on the element property card. (Z1 and Z2 are given on PTRBSC, PQDPLT, PTRPLT, PTRIA1, and PQUAD1 cards. T1 may be specified on the lower surface and T2 on the upper surface for the QUAD2 and TRIA2 elements. These data are not used for membrane elements (Real)

Remarks:

1. Temperature sets must be selected in the Case Control Deck (TEMP=SID) to be used by NASTRAN.

2. If continuation cards are present, EID1 and elements specified on the continuation card(s) are used. Elements must not be specified more than once.

3. If thermal effects are requested all elements must have a temperature field defined either directly on a TEMPP1, TEMPP2, TEMPP3, or TEMPRB card or indirectly as the average of the connected grid point temperatures defined on the TEMP or TEMPD cards. Directly defined element temperatures always take precedence over the average of grid point temperatures.

(Continued)

TEMPP2 (Cont.)

4. The thermal moments in the element coordinate system may be calculated from the formula:

$$\begin{Bmatrix} M_x \\ M_y \\ M_{xy} \end{Bmatrix} = -\int [G_e]\{\alpha_e\}T(z)z\,dz$$

where the integration is performed over the bending material properties in the element coordinate system.

$[G_e]$ - 3x3 elastic coefficient matrix

$\{\alpha_e\}$ - 3x1 material thermal expansion coefficients

$T(z)$ - temperature at z

z - distance from the neutral surface in the element coordinate system.

5. The temperature dependent material properties are evaluated at the average temperature $\bar{T}$. If a property varies with depth, an effective value must be used which satisfies the desired elastic and stress relationships. The temperatures at the fibre distances may be changed to compensate for local differences in α_e and produce correct stresses.

6. Set ID must be unique with respect to all other LØAD type cards if TEMP(LØAD) is specified in Case Control Deck.

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Input Data Card TEMPP3 Plate Element Temperature Field

Description: Defines a temperature field for homogeneous plate, membrane and combination elements (by a tabular description of the thermal field over the cross-section) for determination of:

1) Thermal loading
2) Temperature-dependent material properties
3) Stress recovery.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TEMPP3	SID	EID1	Z0	T0	Z1	T1	Z2	T2	+abc
TEMPP3	17	39	0.0	32.9	2.0	43.4	2.5	45.0	XY1
+abc	Z3	T3	Z4	T4	Z5	T5	Z6	T6	+def
+Y1	3.0	60.0	4.0	90.0					XY2
+def	Z7	T7	Z8	T8	Z9	T9	Z10	T10	+ghi
+Y2									XY3
+ghi	EID2	EID3	EID4	EID5	EID6	EID7	EID8	EID9	+jkl
+Y3	1	2	3	4	5	6	8	10	

-etc.-

Alternate Form of Continuation Card Number 3

+ghi	EID2	"THRU"	EIDi	EIDj	"THRU"	EIDk			+jkl
+Y3				1	THRU	10			

-etc.-

Field	Contents
SID	Temperature set identification number (Integer > 0)
EIDn	Unique element identification number(s) (Integer > 0 or BCD: the continuation card may have THRU in fields 3 and/or 6 in which case EID2 < EIDi, EIDj < EIDk)
Z0	Position of the bottom surface with respect to an arbitrary reference plane (Real)
Zi	Positions on cross-section from bottom to top of cross-section relative to the arbitrary reference plane. There must be an increasing sequence with the last nonzero value corresponding to the top surface (Real)
T0	Temperature at the bottom surface (Real)
Zi	Temperature at position Zi (Real)

Remarks:

1. Temperature sets must be selected in the Case Control Deck (TEMP=SID) to be used by NASTRAN.

2. If the third (and succeeding) continuation card is present, EID1 and elements specified on the third (and succeeding) continuation cards are used. Elements must not be specified more than once.

3. The first and second continuation card must be present if a list of elements is to be used.

(Continued)

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TEMPP3 (Cont.)

4. If thermal effects are requested, all elements must have a temperature field defined either directly on a TEMPP1, TEMPP2, TEMPP3, or TEMPRB card or indirectly as the average of the connected grid point temperatures defined on the TEMP or TEMPD cards. Directly defined element temperatures always take precedence over the average of grid point temperatures.

5. If the element material is temperature dependent, its properties are evaluated at the average temperature over the depth which is calculated by the program using a linear distribution between points.

6. For stress recovery, the temperatures at the extreme points z_0 and z_N are assigned to the bottom surface and the top surface of the elements specified on either PTRIA2 or QUAD2 data card.

7. The data is limited to a maximum of eleven points on the temperature-depth profile.

8. Set ID must be unique with respect to all other LØAD type cards if TEMP(LØAD) is specified in Case Control Deck.

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NASTRAN DATA DECK

Input Data Card TEMPRB One-Dimensional Element Temperature Field

Description: Defines a temperature field for the BAR, RØD, TUBE, and CØNRØD elements for determination of:

1) Thermal loading
2) Temperature-dependent material properties
3) Stress recovery

Format and Example:

1	2	3	4	5	6	7	8	9	10
TEMPRB	SID	EID1	$\bar{T}A$	$\bar{T}B$	T'1a	T'1b	T'2a	T'2b	+abc
TEMPRB	200	1	68.0	23.0	0.0	28.0		2.5	AXY10
+abc	TCa	TDa	TEa	TFa	TCb	TDb	TEb	TFb	+def
+XY10	68.0	91.0	45.0		48.0	80.0	20.0		AXY20
+def	EID2	EID3	EID4	EID5	EID6	EID7	EID8	EID9	+ghi
+XY20	9	10							

-etc.-

Alternate Form for Continuation Card Number 2

+def	EID2	"THRU"	EIDi	EIDj	"THRU"	EIDk			+ghi
+XY20	2	THRU	4	10	THRU	14			

-etc.-

Field	Contents
SID	Temperature set identification number (Integer > 0)
EIDn	Unique element identification number(s) (Integer > 0 or BCD: the second continuation card may have THRU in fields 3 and/or 6 in which case EID2 < EIDi, EIDj < EIDk)
$\bar{T}A$, $\bar{T}B$	Average temperature over the area at end "a" and end"b" (Real)
T'ij	Effective linear gradient in direction i on end j (BAR only, Real)
Tij	Temperatures at point i as defined on the PBAR card(s) at end j. These data are used for stress recovery only (BAR only, Real)

Remarks:

1. Temperature sets must be selected in the Case Control Deck (TEMP=SID) to be used by NASTRAN.

2. If at least one nonzero or nonblank Tij is present, the point temperatures given are used for stress recovery. If no Tij values are given, linear temperature gradients are assumed for stresses.

3. If the second (and succeeding) continuation card is present, EID1 <u>and</u> elements specified on the second (and succeeding) continuation cards are used. Elements must not be specified more than once.

4. If thermal effects are requested, all elements must have a temperature field defined either directly on a TEMPP1, TEMPP2, TEMPP3, or TEMPRB card or indirectly as the average of the connected grid point temperatures defined on the TEMP or TEMPD cards. Directly defined element temperatures always take precedence over the average of grid point temperatures.

(Continued)

TEMPRB (Cont.)

5. The effective thermal gradients in the element coordinate system for the BAR element are defined by the following integrals over the cross-section. For end "a" (end "b" is similar):

$$T'_{1a} = \frac{1}{I_1} \int_A T_a(y,z)y\ dA$$

$$T'_{2a} = \frac{1}{I_2} \int_A T_a(y,z)z\ dA$$

where $T_a(y,z)$ is the temperature at point y,z (in the element coordinate system) at end "a" of the BAR. See Section 1.3, Figure 1 for the element coordinate system: I_1 and I_2 are the moment of inertia about the z and y axis respectively. The temperatures are assumed to vary linearly along the length (x-axis). Note that if the temperature varies linearly over the cross-section then T'_{1a}, T'_{1b}, T'_{2a}, and T'_{2b} are the actual gradients.

6. If the element material is temperature dependent, the material properties are evaluated at the average temperature

$$\frac{\bar{T}_A + \bar{T}_B}{2}$$

7. Set ID must be unique with respect to all other LØAD type cards if TEMP(LØAD) is specified in Case Control Deck.

Input Data Card TF Dynamic Transfer Function

Description: 1. May be used to define a transfer function of the form

$$(B0 + B1p + B2p^2)u_d + \sum_i (A0(i) + A1(i)p + A2(i)p^2)u_i = 0$$

2. May be used as a means of direct matrix input.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TF	SID	GD	CD	B0	B1	B2			+abc
TF	1	2	3	4.0	5.0	6.0			+ABC

+abc	G(1)	C(1)	A0(1)	A1(1)	A2(1)				+def
+ABC	3	4	5.0	6.0	7.0				+DEF

(etc.)

Field	Contents
SID	Set identification number (Integer > 0)
GD,G(i)	Grid, scalar or extra point identification numbers (Integer > 0)
CD,C(i)	Component numbers (Null or zero for scalar or extra points, any <u>one</u> of the digits 1-6 for a grid point)
B0,B1,B2 A0(i),A1(i), A2(i)	Transfer function coefficients (Real)

Remarks: 1. The matrix elements defined by this card are added to the dynamic matrices for the problem.

2. Transfer Function sets must be selected in the Case Control Deck (TFL=SID) to be used by NASTRAN.

3. The constraint relation given above will hold only if no elements are connected to the dependent coordinate.

Input Data Card <u>TIC</u> Transient Initial Condition

Description: Defines values for the initial conditions of coordinates used in Transient analysis. Both displacement and velocity values may be specified at independent coordinates of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TIC	SID	G	C	UO	VO				
TIC	1	3	2	5.0	-6.0				

Field	Contents
SID	Set identification number (Integer > 0)
G	Grid or scalar or extra point identification number (Integer > 0)
C	Component number (Blank or zero for scalar or extra points, any <u>one</u> of the digits 1-6 for a grid point)
UO	Initial displacement value (Real)
VO	Initial velocity value (Real)

Remarks:

1. Transient initial condition sets must be selected in the Case Control Deck (IC=SID) to be used by NASTRAN for structural analysis; however this card should not be used to define initial temperatures in heat transfer analysis. (See Section 2.3.)
2. If no TIC set is selected in Case Control Deck, all initial conditions are assumed zero.
3. Initial conditions for coordinates not specified on TIC cards will be assumed zero.
4. Initial conditions may be used <u>only</u> in direct formulation.

Input Data Card TICS Transient Initial Condition - Substructure Analysis

Description: Defines values for the initial conditions of coordinates used in Direct Transient analysis. Both displacement and velocity values may be specified at independent coordinates of the structural model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TICS	SID	NAME	G	C	U0	V0			
TICS	1	SPAR	3	2	5.0	-6.0			

Field	Contents
SID	Set identification number (Integer > 0)
NAME	Basic substructure name
G	Grid or scalar or extra point identification number (Integer > 0)
C	Component number (Null or zero for scalar or extra points, any one of the digits 1-6 for a grid point)
U0	Initial displacement value (Real)
V0	Initial velocity value (Real)

Remarks:

1. Transient initial condition sets must be selected in the Case Control Deck (IC=SID) to be used by NASTRAN.
2. If no TIC set is selected in Case Control Deck, all initial conditions are assumed zero.
3. Initial conditions for coordinates not specified on TIC cards will be assumed zero.
4. Initial conditions may be used only in direct formulation (Rigid Format 9) and may only be applied to the analysis degrees of freedom, i.e., only those coordinates retained in the solution substructure and not constrained using MPC, SPC, or ØMIT data.
5. Used in substructure SØLVE operation.

Input Data Card TLØAD1 Transient Response Dynamic Load

Description: Defines a time-dependent dynamic load of the form

$$\{P(t)\} = \{A\ F(t - \tau)\}$$

for use in transient response problems.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TLØAD1	SID	L	M		TF				
TLØAD1	5	7	9		13				

Field	Contents
SID	Set identification number (Integer > 0)
L	Identification number of DAREA card set or a thermal load set which defines A (Integer > 0). For automated multi-stage substructuring, reference a DAREAS card set. If desired, the set identification may also reference LØADC cards.
M	Identification number of DELAY or DELAYS card set which defines τ (Integer $\geq$ 0)
TF	Identification number of TABLEDi card which gives $F(t - \tau)$ (Integer > 0)

Remarks:

1. If M is zero, τ will be zero.
2. Field 5 must be blank.
3. Dynamic load sets must be selected in the Case Control Deck (DLØAD=SID) to be used by NASTRAN.
4. TLØAD1 loads may be combined with TLØAD2 loads only by specification on a DLØAD card. That is, the SID on a TLØAD1 card may not be the same as that on a TLØAD2 card.
5. SID must be unique for all TLØAD1, TLØAD2, RLØAD1 and RLØAD2 cards.
6. Field 3 may reference sets containing QHBDY, QBDY1, QBDY2, QVECT, and QVØL cards when using the heat transfer option.
7. If the heat transfer option is used, the referenced QVECT data card may also contain references to functions of time, and therefore A may be a function of time.
8. Fourier analysis will be used if this is selected in an Aeroelastic Response Problem.
9. With automated multi-stage substructuring, DAREAS cards may only reference degrees of freedom in the boundary set of the solution structure.
10. When L references LØADC cards, DAREAS cards with the same set identification and non-zero loads must also exist.

Input Data Card TLØAD2 Transient Response Dynamic Load

Description: Defines a time-dependent dynamic load of the form

$$\{P(t)\} = \begin{cases} \{0\}, & \tilde{t} < 0 \text{ or } \tilde{t} > T2 - T1 \\ \left\{A\ \tilde{t}^{B}\ e^{C\tilde{t}} \cos(2\pi F\tilde{t} + P)\right\}, & 0 \le \tilde{t} \le T2 - T1 \end{cases}$$

for use in transient response problems where $\tilde{t} = t - T1 - \tau$.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TLØAD2	SID	L	M		T1	T2	F	P	abc
TLØAD2	4	10	7		2.1	4.7	12.0	30.0	+12
+bc	C	B							
+12	2.0	3.0							

Field	Contents
SID	Set identification number (Integer > 0)
L	Identification number of DAREA card set or a thermal load set which defines A (Integer > 0). For automated multi-stage substructuring, reference a DAREAS card set. If desired, the set identification may also reference LØADC cards.
M	Identification number of DELAY or DELAYS card set which defines τ (Integer $\geq$ 0)
T1	Time constant (Real $\geq$ 0.0)
T2	Time constant (Real, T2 > T1)
F	Frequency in cycles per unit time (Real $\geq$ 0.0)
P	Phase angle in degrees (Real)
C	Exponential coefficient (Real)
B	Growth coefficient (Real)

Remarks:

1. If M is zero, τ will be zero.
2. Field 5 must be blank.
3. Dynamic load sets must be selected in the Case Control Deck (DLØAD=SID) to be used by NASTRAN.
4. TLØAD2 loads may be combined with TLØAD1 loads only by specification on a DLØAD card. That is, the SID on a TLØAD2 card may not be the same as that on a TLØAD1 card.
5. SID must be unique for all TLØAD1, TLØAD2, RLØAD1 and RLØAD2 cards.

(Continued)

TLØAD2 (Cont.)

6. Field 3 may reference load sets containing QHBDY, QBDY1, QBDY2, QVECT, QVØL and SLØAD cards when using the heat transfer option.

7. If the heat transfer option is being used, the referenced QVECT load card may also contain references to functions of time, and therefore A may be a function of time.

8. Fourier analysis will be used if this selection is an Aeroelastic Response problem.

Input Data Card TRANS   Component Substructure Transformation Definition

Description: Defines the location and orientation of the component substructure basic coordinate system axes relative to the basic coordinate system of the substructure formed as a result of the substructure CØMBINE operation. The translation and rotation matrices are defined by specifying the coordinates of three points A, B, C. The coordinates of points A, B, C must be expressed on this card in the basic coordinate system of the resultant combined substructure as follows:

A - defines the location of the origin of the basic coordinate system of the component substructure.

B - defines the location of a point on the z axis of the basic coordinate system of the component substructure.

C - defines the location of a point in the positive x side of the xz plane of the basic coordinate system of the component substructure.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TRANS	CID		A1	A2	A3	B1	B2	B3	abc
TRANS	1		0.0	0.0	0.0	0.0	-0.5	10.0	ABC

+bc	C1	C2	C3						
+BC	0.0	10.0	0.5						

Field	Contents
CID	Set identification number (Integer > 0)
A1, A2, A3 B1, B2, B3 C1, C2, C3	Coordinates of the points defining system as described above.

Remarks:
1. Continuation card must be present.
2. Coordinates A, B, C are given in BASIC coordinate system of the result substructure.
3. The value of CID must be unique with respect to all other TRANS data cards.
4. Transformation sets for a whole substructure must be selected in the Substructure Control Deck (TRANS=SID) to be used by NASTRAN. Note that 'TRANS' is a subcommand of the substructure CØMBINE command.
5. Transformation of individual grid points in a substructure prior to combining them is requested by the GTRAN Bulk Data card which references the TRANS information.
6. The three points (A1,A2,A3), (B1,B2,B3), (C1,C2,C3) must be unique and non-collinear.

Input Data Card TSTEP Transient Time Step

Description: Defines time step intervals at which solution will be generated and output in Transient Analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TSTEP	SID	N(1)	DT(1)	NØ(1)					+abc
TSTEP	2	10	.001	5					+ABC
+abc		N(2)	DT(2)	NØ(2)					+def
+ABC		9	0.01	1					+DEF

(etc.)

Field	Contents
SID	Set identification number (Integer > 0)
N(i)	Number of time steps of value DT(i) (Integer ≥ 2)
DT(i)	Time increment (Real > 0.0)
NØ(i)	Skip factor for output (Every NØ(i)th step will be saved for output) (Integer > 0)

Remarks:

1. TSTEP cards must be selected in the Case Control Deck (TSTEP=SID) in order to be used by NASTRAN.

2. In Aeroelastic Response problems, this card is required only when TLØAD is requested, i.e., when Fourier methods are selected.

2.5 USER'S MASTER FILE

As a means of aiding the user in handling the large (several boxes of cards) Bulk Data Decks which are typical of NASTRAN problems, the User's Master File is provided for storage of many Bulk Data Decks on a single tape. In the context of this Section, a "tape" is synonomous with both a physical tape or a disk file. (See Section 2.1 for the use of the FILES parameter on the NASTRAN card.)

There are many advantages to using a Master File. The User's Master File provides a convenient common source of data. Errors due to card handling are sharply reduced since a several box input deck is reduced to a few cards. Finally, the convenience to the user in submitting jobs should be emphasized.

2.5.1 Use of User's Master File

Functionally, the User's Master File exhibits all of the properties of an Old Problem Tape (ØPTP) which would result if a job were terminated after the NASTRAN preface; only the control cards used are different. Thus the User's Master File (UMF) becomes an alternate source of bulk data input to NASTRAN which may be modified in identically the same way as bulk data is changed during a modified restart. Since the UMF is used as an alternate ØPTP functionally, only one or the other may appear in a run. The UMF, then, is used only for an initial run and may not be used in conjunction with a restart. The checkpoint feature may be used with a UMF run, however, and the resulting New Problem Tape (NPTP) may be used as an ØPTP in a subsequent restart.

In describing the use of the User's Master File, the UMF control cards will be contrasted with their ØPTP counterparts. In place of the setup card for the ØPTP tape (see Section 5 of the Programmer's Manual for a discussion of these machine and installation dependent NASTRAN driver control cards), use a setup card for the selected UMF tape. In place of the restart dictionary in the Executive Control Deck, use the card

$$\text{UMF} \quad k_1, k_2$$

described in Section 2.2.1, which selects Bulk Data Deck k_2 from UMF tape k_1 to use in the current execution.

2.5.2 Using the User's Master File Editor

To assist the NASTRAN user in creating and maintaining User's Master Files, an auxiliary NASTRAN preface module, the User's Master File Editor, is provided. The functions performed by the Editor are:

1. Create a New User's Master File (NUMF) from Bulk Data Decks supplied by the user.
2. List and/or punch Bulk Data Decks from an already existing UMF.
3. Edit Bulk Data Decks (which may be modified) from an old UMF onto a NUMF.

Bulk Data Decks must be acceptable to the NASTRAN preface (XSØRT and IFP) to be accepted by the Editor.

The executive control card that causes NASTRAN to execute as the User's Master File Editor is UMFEDIT. When in the Editor mode, NASTRAN executes only the preface. A separate run is required to use a User's Master File generated by the Editor. Preface module UMFEDT, which is where the User's Master File Editor actions occur, reads data cards from the System Input Stream which are used to control Editor activity. Some of these data cards precede the Bulk Data Deck being processed while others follow. The remainder of this section will be devoted to describing these cards and the action caused by them. Section 2.5.3 gives some rules to be followed when making up data cards for the Editor. Several examples will then be given in Section 2.5.4 to illustrate the functions performed by the User's Master File Editor.

Table 1 shows the Editor data cards and describes the action taken for each one. Three classes are described, depending on the tapes used. The cards are free-field format as are the executive control cards and case control cards previously described. The symbolic quantities tid and pid are each up to 8 arbitrarily selected integers chosen by the user who causes the User's Master File to be created. Table 2 shows a summary of Editor control cards.

When a New User's Master File (NUMF) is created, the User's Master File Editor (UMFEDIT) punches the Executive Control cards that are needed to read the decks from the newly created master file. The UMFEDIT automatically punches one UMF Executive Control card for each Bulk Data Deck that is written on the NUMF and lists it in a table of contents.

2.5.3 Rules for the User's Master File Editor

1. The tape identification number, tid, and the problem identification number, pid, are positive integers selected by the user. The only exception to this is that pid may be zero if the UMF card is being used only to specify a value for tid or to indicate a new deck rather than an alter set.

2. The tape identification number, tid, must be the same for all decks on a single UMF.

3. Only one pass is made while either reading the UMF or writing the NUMF. Sequential processing requests are thereby required. This means that the problem identification numbers must form an increasing sequence corresponding to the order of the decks.

4. A corollary to 2 is that a deck to be inserted between two decks on an existing UMF must be given a problem identification number whose value "lies between" the values of the problem identification numbers for the two UMF decks. Thus, an initial numbering sequence such as 10, 20, 30, ... is recommended.

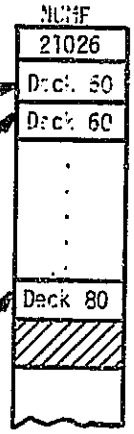
5. Most NASTRAN users develop the habit of "storing" data cards not needed for a given run behind the ENDDATA card where they are normally ignored. This must not be done when using the Editor since it reads data from this position. Data cards following the FINIS card are ignored, however.

2.5.4 Examples of User's Master File Editor Usage

Several examples of User's Master File Editor usage are given in this section. The user is well-advised to study these examples both from the standpoint of understanding the functioning of the Editor and from the standpoint of learning how to use this NASTRAN feature. A symbolic representation of the contents of the UMF and/or NUMF used in each example is given along with an explanation of specific items of interest. These examples illustrate all of the capability of the User's Master File Editor.

Example 1. Create a User's Master File

```
ID  A,B
TIME 1
APP DMAP
BEGIN
END
UMFEDIT
CEND
TITLE = USER'S MASTER FILE CØNTAINS
LABEL = PRØBLEMS 50, 60, ..., 80
ECHØ = BØTH
MAXLINES=50000
BEGIN BULK  }
    .       }
    .       }  1st Bulk Data Deck
    .       }
ENDDATA     }
NUMF  21026, 50
BEGIN BULK  }
    .       }
    .       }  2nd Bulk Data Deck
    .       }
ENDDATA     }
NUMF  21026, 60
    .
    .
    .
    .
    .
BEGIN BULK  }
    .       }
    .       }  Last Bulk Data Deck
    .       }
ENDDATA     }
NUMF  21026, 80
FINIS
```



Notes: 1. A tape must be set up for NASTRAN file NUMF.

2. A tape must not be set up for NASTRAN file UMF.

3. The DMAP sequence will not be used but must appear in the Executive Control Deck.

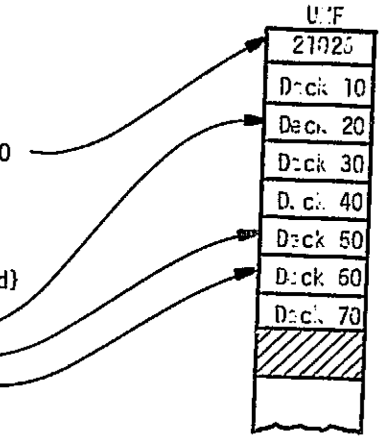
4. ECHØ = BØTH is recommended since the unsorted Bulk Data Deck is available only during the run used to create the User's Master File. The sorted echo is needed in order to make alterations to the bulk data when using the User's Master File in a NASTRAN run.

5. Note that the tape identification number, tid, is the same on all of the NUMF cards.

6. Note that the problem identification numbers, pid, are increasing according to the data deck order.

Example 2. List and/or punch selected decks from a User's Master File

```
ID  A,B
TIME 1
APP DMAP
BEGIN
END
UMF  21026, 0
UMFEDIT
CEND
ECHØ=NØNE
BEGIN BULK
  {blank card}
ENDDATA
LIST  20
PUNCH  50
PUNPRT  60
FINIS
```



Notes: 1. A tape containing the proper User's Master File must be set up on NASTRAN file UMF.

2. A tape must not be set up for NASTRAN file NUMF.

3. The DMAP sequence will not be used but must appear in the Executive Control Deck.

4. The dummy Bulk Data Deck consisting of a single blank card will not be used but must appear.

5. ECHØ = NØNE is recommended to suppress printout of the dummy Bulk Data Deck. This has no effect on the User's Master File Editor.

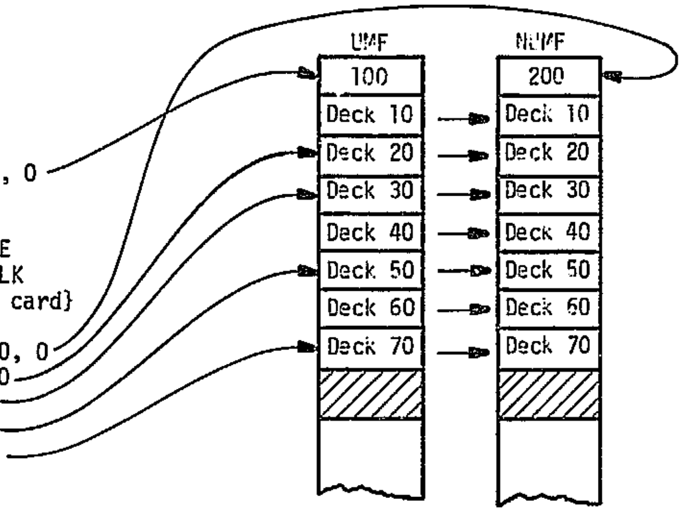
6. The zero value of pid on the UMF card is required since only tid is being used in this application.

7. The LIST, PUNCH, and PUNPRT cards must be sequenced such that the pid values form an increasing sequence.

8. The above requests will cause a sorted Bulk Data Deck echo to be made for decks 20 and 60; decks 50 and 60 will be punched.

Example 3. Copy a User's Master File while listing and/or punching selected decks.

```
ID  A,B
TIME 5
APP DMAP
BEGIN
END
UMF  100, 0
UMFEDIT
CEND
ECHØ=NØNE
BEGIN BULK
  {blank card}
ENDDATA
NUMF  200, 0
PUNPRT 20
LIST 30
LIST 50
PUNCH 70
FINIS
```



Notes:

1. A tape containing the User's Master File to be copied must be set up on NASTRAN file UMF.

2. A tape must be set up on NASTRAN file NUMF.

3. The DMAP sequence is not used but must appear in the Executive Control Deck.

4. The dummy Bulk Data Deck consisting of a single blank card will not be used but must appear.

5. ECHØ = NØNE is recommended to suppress printout of the dummy Bulk Data Deck. This has no effect on the User's Master File Editor.

6. The zero value of pid on the UMF card is required since only tid is being used in this application.

7. The zero value of pid on the NUMF card is not used. This card is used to specify tid for the NUMF. If the NUMF card were absent, the same tid would be put on the NUMF as existed on the UMF.

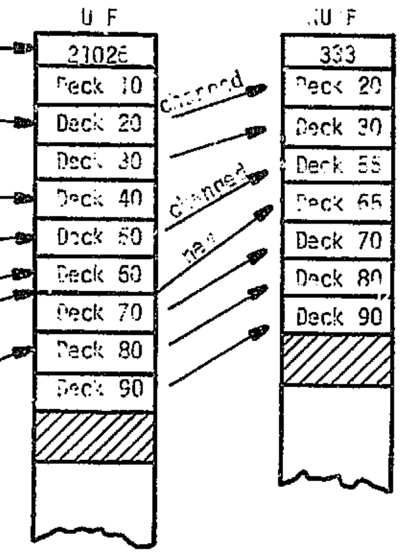
8. The LIST, PUNCH, and PUNPRT cards must be sequenced such that the pid values form an increasing sequence.

9. The above requests will cause a sorted Bulk Data Deck echo to be made for decks 20, 30, and 50; decks 20 and 70 will be punched.

10. All of the decks contained on the UMF will be copied onto the NUMF tape. The tape identification number will be different as explained in note 7.

Example 4. Edit a User's Master File

```
ID A,B
TIME 5
APP DMAP
BEGIN
END
UMF  21026, 20
UMFEDIT
CEND
TITLE = MØDIFICATIØN ØF
SUBTITLE = DECKS 20 AND 50
ECHØ = BØTH
BEGIN BULK
  {alter cards for Deck 20}
ENDDATA
NUMF  333, 20
REMØVE 40
UMF  21026, 50
BEGIN BULK
  {alter cards for Deck 50}
ENDDATA
NUMF  333, 55
REMØVE 60
UMF  21026, 0
BEGIN BULK
  {Deck 65}
ENDDATA
NUMF 333, 65
LIST 80
FINIS
```



Notes:
1. A tape containing the User's Master File to be edited must be set up on NASTRAN file UMF.

2. A tape must be set up on NASTRAN file NUMF.

3. The DMAP sequence is not used but must appear in the Executive Control Deck.

4. ECHØ = BØTH is recommended since the alter cards are available only during the run used to perform the edit. The sorted echo is needed for those decks being altered in order to make further alterations to the bulk data when using the newly created User's Master File in a NASTRAN run. Decks not being altered will not be echoed as a result of the ECHØ = BØTH card. Such decks may be echoed as they are copied as shown in the example for Deck 80.

5. The pid values must form an increasing sequence.

6. The requests in the above example will cause listings to be generated for deck 80; no decks will be punched.

7. Decks 30, 70, 80, and 90 will be copied onto the NUMF with no changes.

8. Decks 10, 40, and 60 will be removed (i.e., not copied onto the NUMF).

9. Decks 20 and 50 will be modified. In addition the problem identification number of Deck 50 will be changed to 55.

10. Deck 65 will be added.

11. Deck 10 is removed because it appears prior to the first call to the Editor. This may be avoided by using a pid of zero and a dummy Bulk Data Deck as shown in Example 3.

Table 1. User's Master File Editor Control Card Actions.

I. UMF Only is Present

- A. FINIS
  1. Terminate run.
- B. BEGIN BULK (Not Allowed)
- C. REMØVE pid (Not Allowed)
- D. LIST pid
  1. Skip UMF forward to pid and list the Bulk Data Deck on the printer.
- E. PUNCH pid
  1. Skip UMF forward to pid and punch the Bulk Data Deck on the punch.
- F. UMF tid, pid (Not Allowed)
- G. NUMF tid, pid (Not Allowed)
- H. PUNPRT pid
  1. Skip UMF forward to pid and then list and punch the Bulk Data Deck.
- I. PRINT tid
  1. List all Bulk Data Decks and Summary Table of Contents.
- J. TØC tid
  1. List all Bulk Data Decks Summary Table of Contents.

II. NUMF Only is Present

- A. FINIS
  1. Write end-of-file on NUMF.
  2. Terminate run.
- B. BEGIN BULK
  1. Process the next Bulk Data Deck.
- C. REMØVE pid (Not Allowed)
- D. LIST pid (Not Allowed)
- E. PUNCH pid (Not Allowed)
- F. UMF tid, pid (Not allowed)
- G. NUMF tid, pid
  1. If first entry to Editor, write tape identification file on NUMF.
  2. Add preceding Bulk Data to NUMF and automatically punch and list the UMF card for use with UMF.
- H. PUNPRT pid (Not Allowed)
- I. TØC tid (Not Allowed)
- J. PRINT tid (Not Allowed)

III. Both UMF and NUMF are Present

- A. FINIS
  1. Copy any remaining Bulk Data Decks from UMF to NUMF.
  2. Write end-of-file on NUMF.
  3. Terminate run.
- B. BEGIN BULK
  1. Process the next Bulk Data Deck which may be a new deck or a modified deck from the UMF.
- C. REMØVE pid
  1. Copy UMF onto NUMF up to indicated deck.
  2. Skip indicated deck on UMF.
- D. LIST pid
  1. Copy UMF onto NUMF through indicated deck.
  2. List indicated Bulk Data Deck on printer.
- E. PUNCH pid
  1. Copy UMF onto NUMF through indicated deck.
  2. Punch indicated Bulk Data Deck on printer.
- F. UMF tid, pid
  1. Copy UMF onto NUMF up to indicated deck. (Must be immediately followed by BEGIN BULK card.)
- G. NUMF tid, pid
  1. If first entry to Editor, write tape identification file on NUMF.
  2. Copy UMF onto NUMF up to deck with identification greater than pid.

(Continued)

Table 1. User's Master File Editor Control Card Actions. (Continued)

G. 3. Add preceding Bulk Data Deck to NUMF and automatically punch and list the UMF card for use with UMF.

H. PUNPRT pid
1. Copy UMF onto NUMF through indicated deck.
2. List indicated Bulk Data Deck on printer.
3. Punch indicated Bulk Data Deck on punch.

I. TØC tid (Not Allowed)

J. PRINT tid (Not Allowed)

Table 2. Summary of User's Master File Editor Control Cards.

LIST pid	List the problem deck from UMF or copy the problem deck from UMF onto NUMF and list it.
NUMF tid, pid	Add problem deck to NUMF, list it and punch UMF card.
PRINT tid	List all problem decks from UMF and Summary Table of Contents.
PUNCH pid	Punch the problem deck from UMF or copy the problem deck from UMF onto NUMF and punch it.
PUNPRT pid	Punch and print the problem deck from UMF or copy the problem deck from UMF onto NUMF and punch and print it.
REMØVE pid	Copy problem decks from UMF onto NUMF up to pid and skip over problem pid.
TØC tid	List all problem decks (Summary Table of Contents) by UMF number from UMF.
UMF tid, pid	Copy UMF problem deck onto NUMF, list it and punch UMF card.

2.6 USER GENERATED INPUT

It may happen that a user will want to take a problem previously run on another program and run it using NASTRAN. In many instances, this provides the user with the quickest means of familiarizing himself with NASTRAN since he is running a problem which he understands intimately. Also, he may wish to extend his analysis of some previously analyzed problem into regions which previous programs would not allow. In either event, he is faced with the problem of Input Data conversion.

The simplest way to convert structural model data is to write a small FØRTRAN (or other language) program to read in the data cards composing the input data deck for the previous program and punch a new NASTRAN Bulk Data Deck. Usually, the information is in a one to one correspondence, and this procedure is quite straight forward, requiring only a minimal knowledge of programming. While a large deck of cards may result, by using the User's Master File feature described in Section 2.5, the amount of large deck handling may be minimized.

2.6.1 Utility Module INPUT Usage

NASTRAN has implemented one data generating utility module within its existing structure for specific cases. General characteristics of the INPUT module are as follows:

1. INPUT allows the user of NASTRAN to generate the majority of the bulk data cards for a number of selected test problems without having to actually input the physical cards into the Bulk Data Deck.

2. The test problems for which partial data are generated by INPUT are:

   a. N x N Laplace Network from scalar elements

   b. W x L Rectangular Frame from BAR elements or RØD elements

   c. W x L Rectangular Array of QUAD1 elements

   d. W x L Rectangular Array of TRIA1 elements

   e. N - segment string from scalar elements

   f. N - cell beam made from BAR elements

   g. N - scalar point full matrix with optional unit loading

   h. N - spoke wheel

   These problem types are described separately in the following sections.

3. To use INPUT variations of the following alter deck must be used:

```
ALTER 1
PARAM //C,N,NØP/V,N,TRUE=-1 $
INPUT,    ,,,,/G1,G2,----,G5/C,N,a/C,N,b/C,N,b $
EQUIV G1,GEØM1/TRUE  /  G2,GEØM2/TRUE----/ G5,GEØM5/TRUE $
ENDALTER
```

The specific data blocks that need be included depend on the particular problem as do the parameter values. Examples for each problem type will be given.

4. Data cards are read by INPUT from the System Input File using FØRTRAN I/Ø, each card containing up to 10 eight column fields. Remember to right-justify this data. The required data are described in each problem type description.

5. The INPUT data card(s) follow the ENDDATA card. Do not "store" other data that is not intended to be used by the INPUT module.

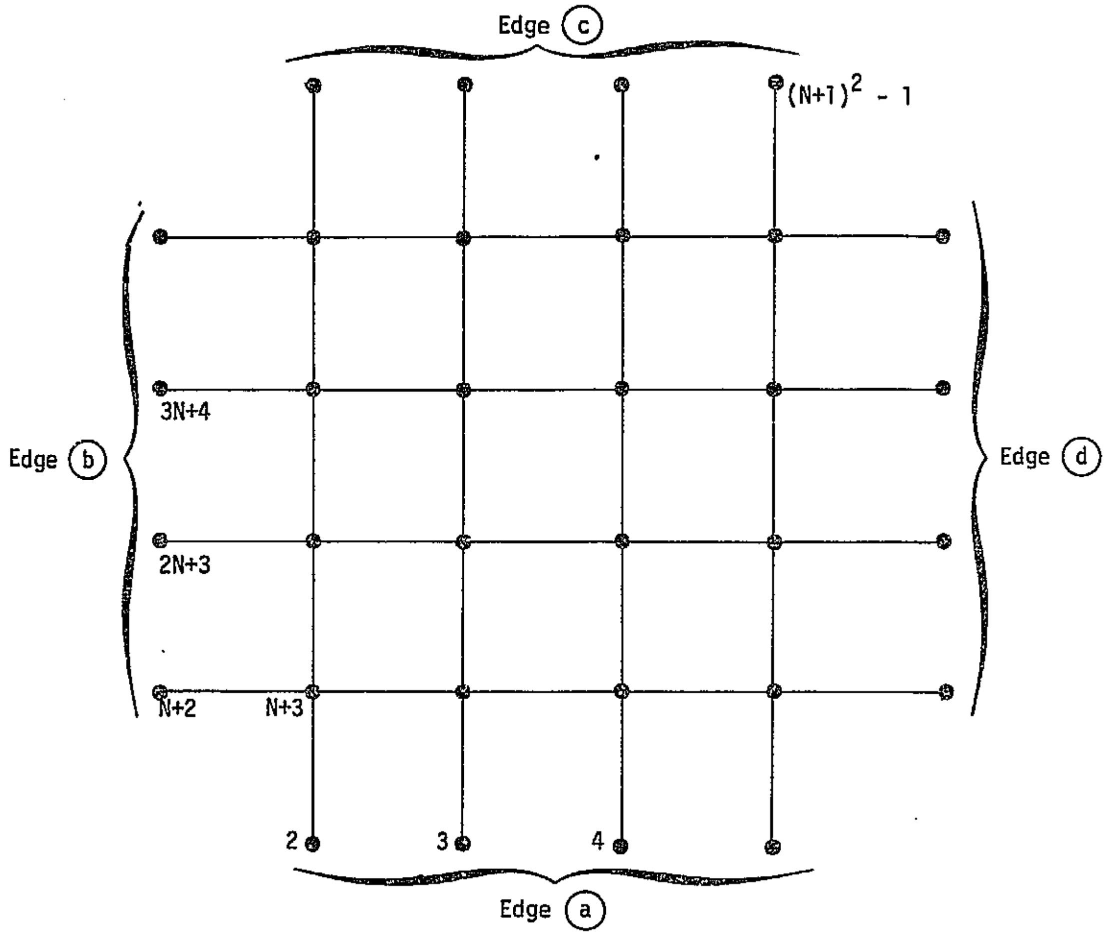
6. Several sample problems were run as part of checkout. The input for these runs are available as examples of INPUT usage.

7. Restart tables are not effective with respect to "cards" generated by INPUT since the preface is unaware of their existance.

8. The INPUT data generator feature is restrictive. It can only be used in the circumstances illustrated. The user may employ the INPUT module as described but merging of user data with INPUT data is not supported. As an example, single point constraints may be defined either in the bulk data deck or in the INPUT module data deck but not both places in an attempt to combine them. Thus if SPC cards are defined in the bulk data deck, then the G4 data block will not be generated and GEØM4 must not be equivalenced to G4.

2.6.1.1 Laplace Circuit (a=1, b=1,2 or 3, c is not used)

INPUT generates CELAS4, SPØINT, SPC (for b=1), and CMASS4 (for b=2,3) cards for the circuit shown.



The scalar point id's are 1 through $(N+1)^2$ except for 1, N+1, N(N+1)+1, and $(N+1)^2$. For b = 2 or 3, all edge points are replaced with ground. The scalar elements generated are shown below for each value of b for a typical cell. Elements between edge points are not generated.

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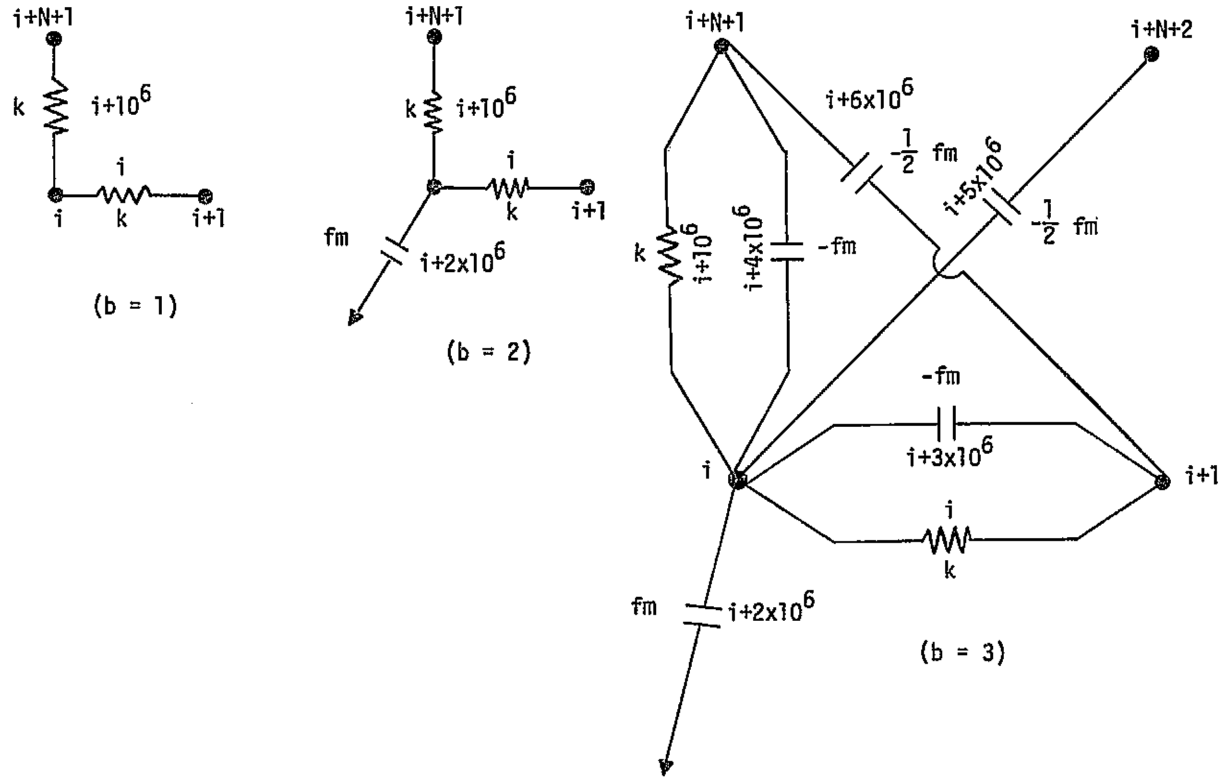
OF POOR QUALITY



a. Data Card

1	N	(I8)	N^2 = no. of cells
2	k	(E8.0)	Spring stiffness
3	U	(E8.0)	Enforced displacement along edge (b) (b = 1)
3	m	(E8.0)	Mass (b = 2,3)
4	f	(E8.0)	Coupling fraction (b = 3 only)

b. Options

b = 1, statics. Use statics (Rigid Format D-1) to solve $\nabla^2 u = 0$ with boundary conditions u = 0 along (a), (c) and (d), u = U along (b). G2 and G4 are both used. No masses are generated.

b = 2, no mass coupling. Use real eigenvalue analysis (Rigid Format D-3) to obtain the eigenvalues of a square membrane ($\nabla^2 u = \frac{\partial^2 u}{\partial t^2}$) where the theoretical solutions for $N \rightarrow \infty$ are given by

$$f_{ij} = \frac{1}{N}\{i^2 + j^2\}^{1/2} \; ; \quad i,j = 1,2,---$$

U is ignored. **Only** G2 is used. Diagonal masses only are generated.

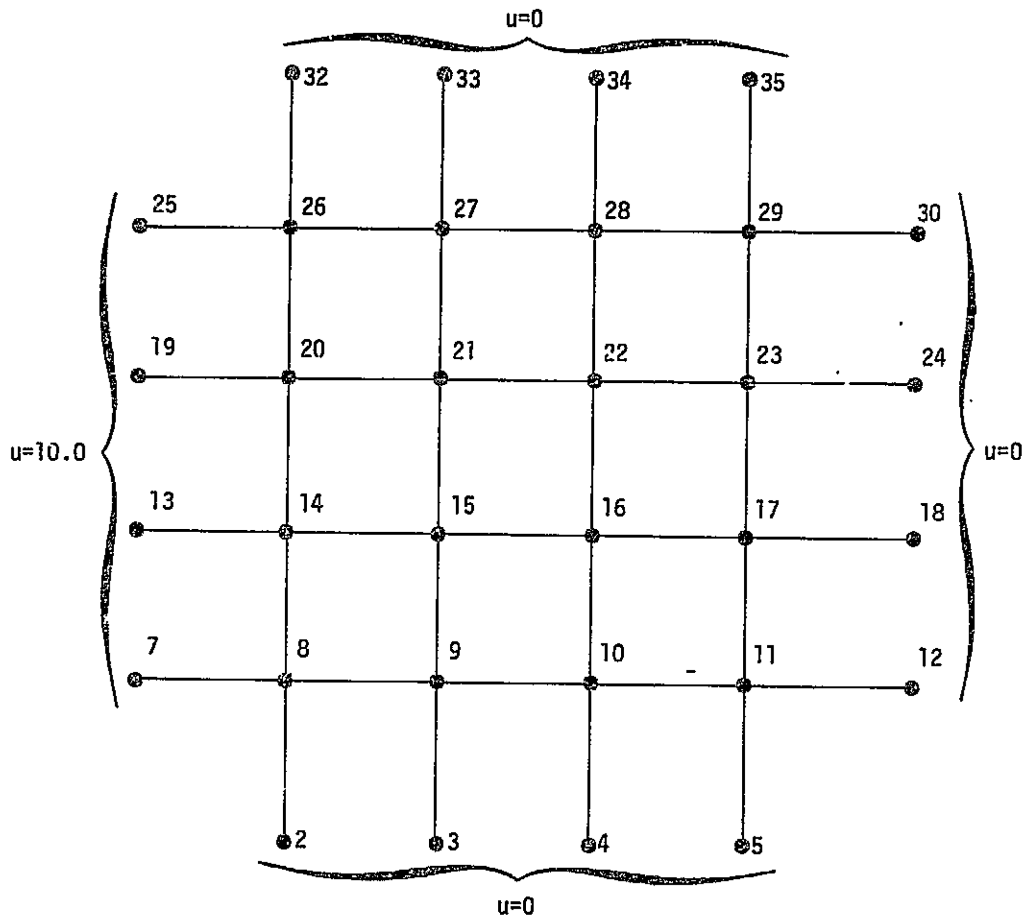
b = 3, mass coupling. Same as where the diagonal masses are m. The horizontal and vertical masses are -fm; the cross diagonal masses are $-\frac{1}{2}$ fm.

c. Notes

(1) For b = 1, SPR = 1000+N must be selected in Case Control Deck.

NASTRAN DATA DECK

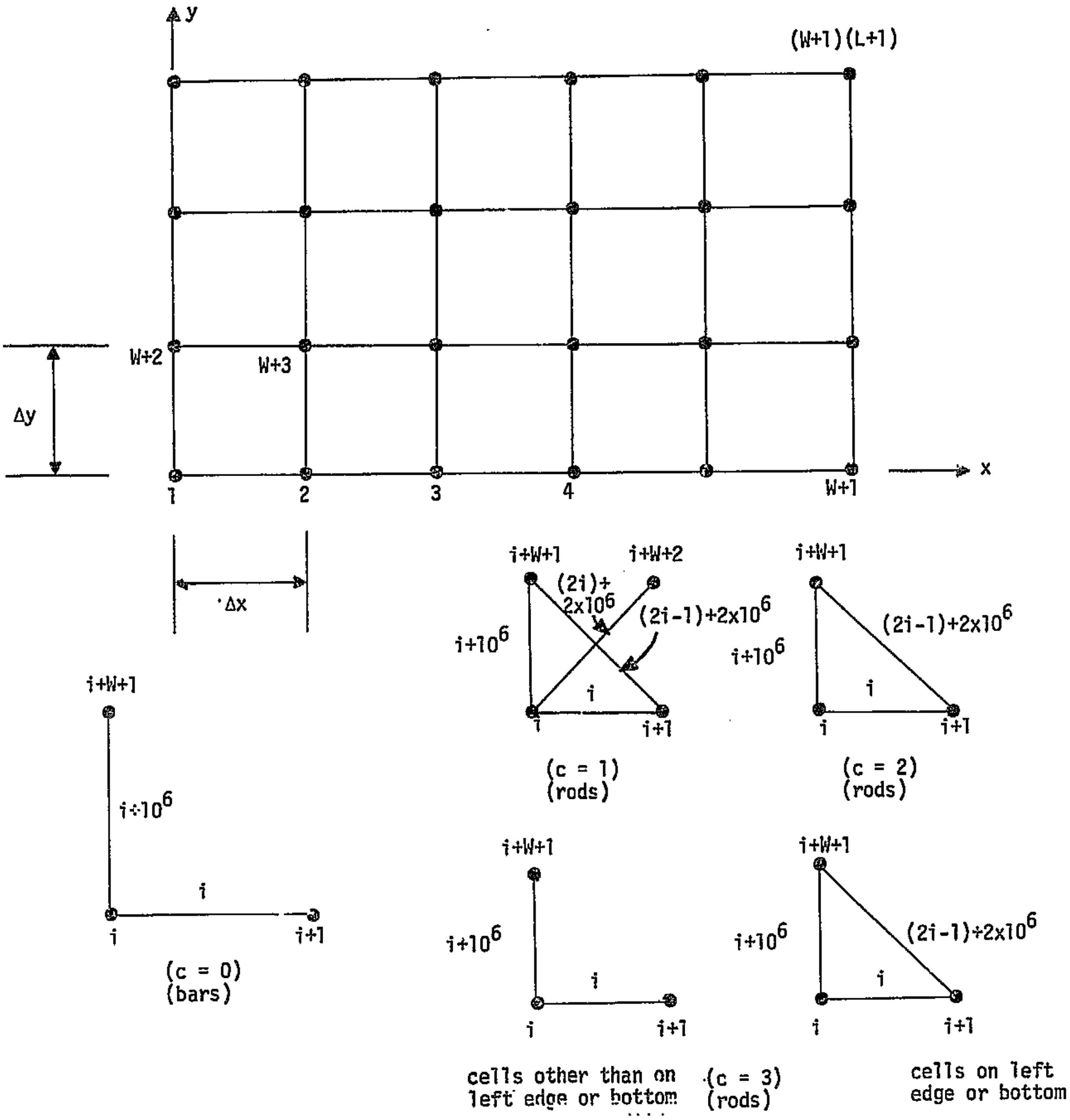
```
ID INPUT,CASE1
TIME 30
APP DISP
SØL 1,3
ALTER 1
PARAM //C,N,NØP/V,N,TRUE=-1 $
INPUT, ,,,,/,G2,,G4,/C,N,1/C,N,1 $
EQUIV G2,GEØM2/TRUE  /  G4,GEØM4/TRUE $
ENDALTER
CEND
ECHØ=BØTH
TITLE=TEST ØF UTILITY MØDULE INPUT
SUBTITLE=LAPLACE CIRCUIT
LABEL=STATICS
SPC=1005
ØUTPUT
DISP=ALL
BEGIN BULK
{blank card}
ENDDATA
      5       1.0      10.0
```



Lines indicate scalar springs

2.6.1.2 Rectangular Frame made from BARs or RØDs (a=2, b=1,2,3 or 4, c=0,1,2 or 3)

INPUT generates GRID, CBAR or CRØD and SEQGP cards for the rectangular frame shown.



a. Data Card

1	W	(I8)	No. cells in x-direction
2	L	(I8)	No. cells in y-direction
3	Δx	(E8.0)	Length of cell in x-direction
4	Δy	(E8.0)	Length of cell in y-direction
5	P	(I8)	Permanent single-point constraints

b. Options (SEQGP cards)

b
- =1, Regular Banding (no SEQGP cards generated)
- =2, Double Banding
- =3, Active Columns
- =4, Reverse Double Banding

c
- =0, Bars
- =1, Rods with both diagonals
- =2, Rods with UL - LR diagonals
- =3, Rods - statically determinate

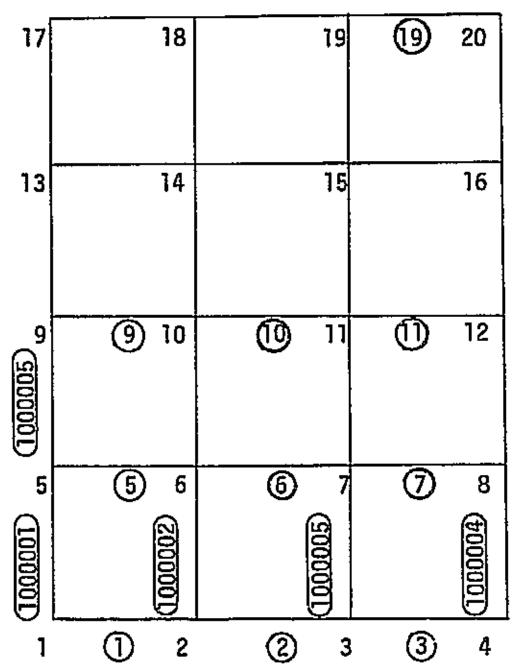
c. Notes

(1) A PBAR card with PID of 101 must be supplied as part of the Bulk Data for c = 0; for c ≠ 0, this is a PRØD card.

(2) If b = 1, SEQGP cards may be included in the Bulk Data.

USER GENERATED INPUT

```
ID INPUT, CASE2
TIME 30
APP DISP
SØL 1,3
ALTER 1
PARAM //C,N,NØP/V,N,TRUE=-1 $
INPUT, ,,,,/G1,G2,,,/C,N,2/C,N,1 $
EQUIV G1,GEØM1/TRUE  /  G2,GEØM2/TRUE  $
ENDALTER
CEND
ECHØ=BØTH
TITLE=TEST ØF UTILITY MØDULE INPUT
SUBTITLE=RECTANGULAR FRAME FRØM BARS
LABEL=REGULAR BANDING
SPC=1
LØAD=1
ØUTPUT
SET 101 = 1,4,17,20
DISP=101
BEGIN BULK
FØRCE          1      20       0      1.0     1.0     0.0     0.0
MAT1           7     1.0     1.0
PBAR         101       7     1.0      2.0     4.0     8.0
SPC            1       1    1234      0.0       4      23     0.0
ENDDATA
       3       4     1.0     2.0      345
```



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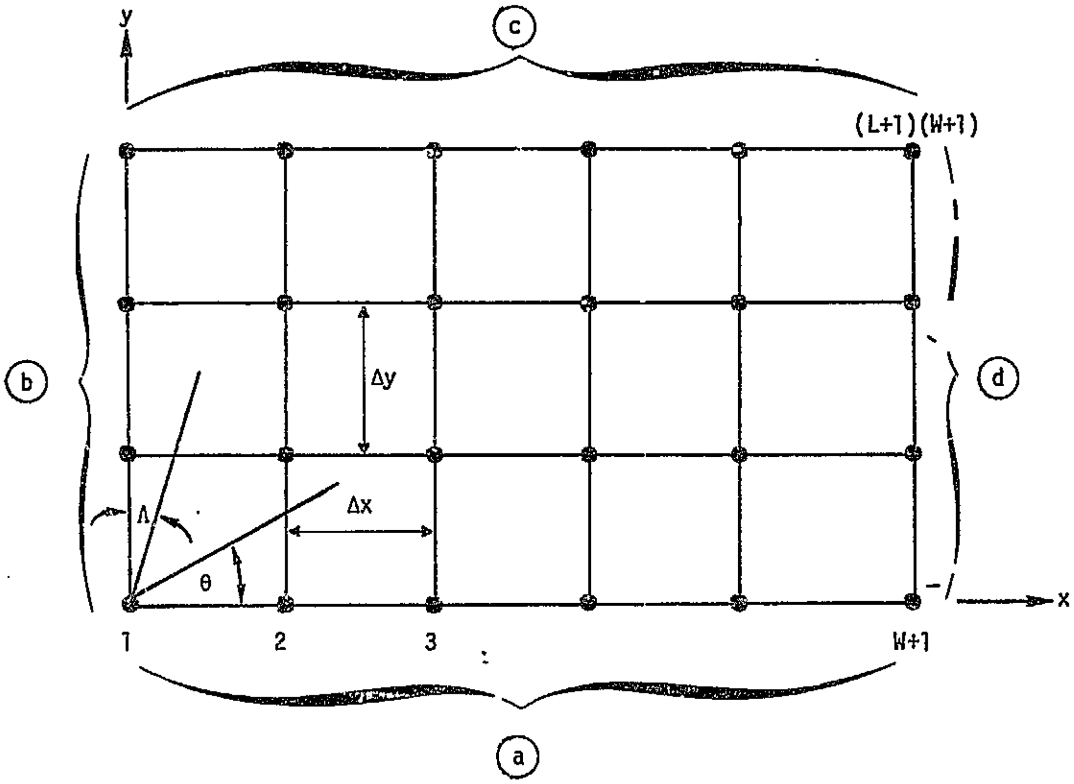
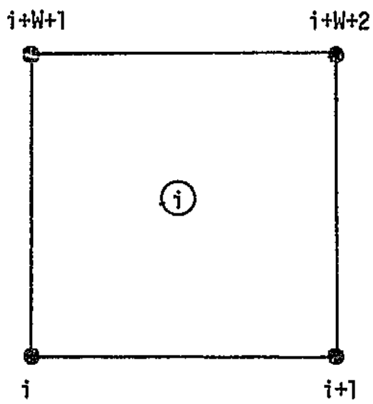
2.6.1.3 Rectangular Plate made from QUAD1s (a=3, b=1,2,3 or 4, c is not used)

INPUT generates GRID, CQUAD1, SEQGP, ØMIT (if requested), and SPC (if requested) cards for the rectangular grid work shown.





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USER GENERATED INPUT

a. Data Deck (2 cards required)

First Card

1	W	(I8)	No. cells in x-direction
2	L	(I8)	No. cells in y-direction
3	ΔX	(E8.0)	Length of cell in x-direction
4	Δy	(E8.0)	Length of cell in y-direction
5	IP	(I8)	Permanent Constraints
6	Λ	(E8.0)	Sweep angle in degrees
7	θ	(E8.0)	Material orientation angle in degrees

Second Card

1	IYO	(I8)	SPC's on y = 0
2	IXO	(I8)	SPC's on x = 0
3	IYL	(I8)	SPC's on $y = L \cdot \Delta y$
4	IXW	(I8)	SPC's on $x = W \cdot \Delta x$
5	IØX	(I8)	ØMIT's in x-direction
6	IØY	(I8)	ØMIT's in y-direction

b. Options (SEQGP cards)

$$b \begin{cases} =1, \text{ Regular banding (no SEQGP cards generated)} \\ =2, \text{ Double banding} \\ =3, \text{ Active banding} \\ =4, \text{ Reverse double banding} \end{cases}$$

c. Notes

(1) If IP, IYØ, IXØ, IYL, IXW, IØX, and IØY are all zero, data block G4 will be purged.

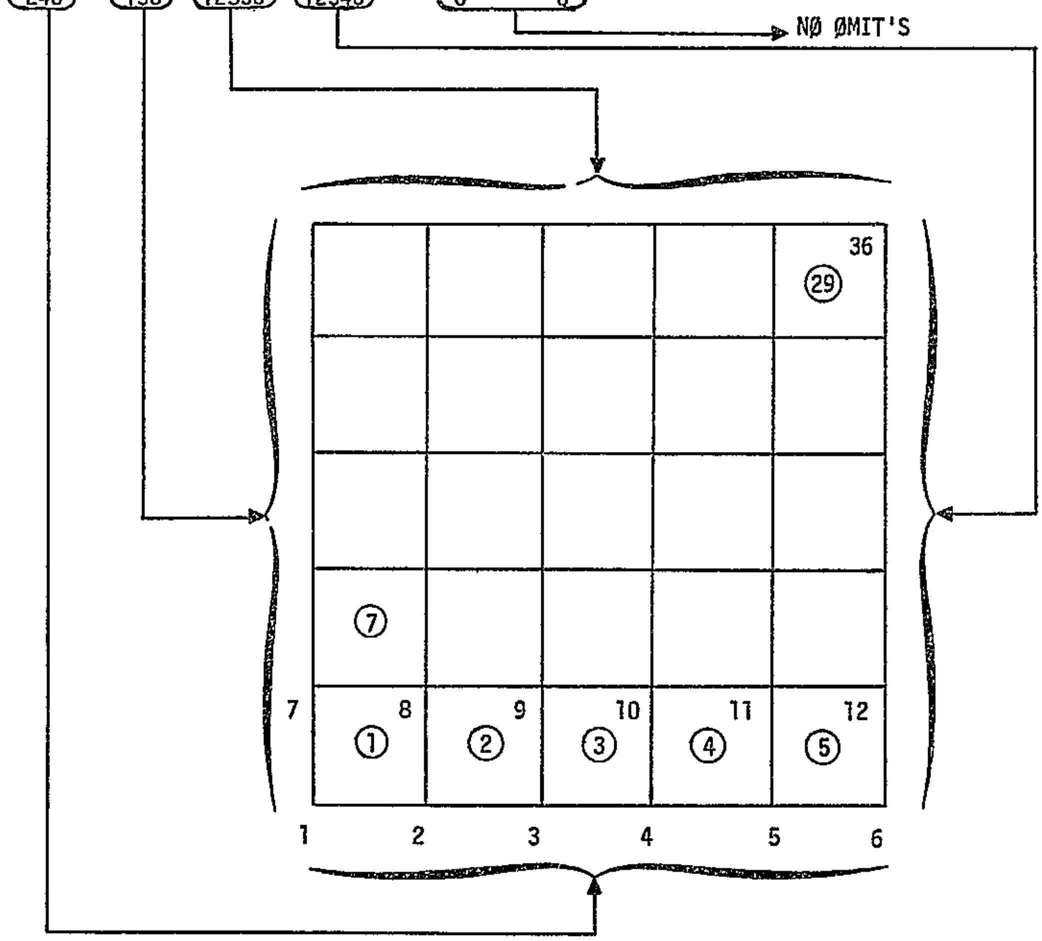
(2) A PQUAD1 card with PID = 101 must be included in the Bulk Data.

(3) IF SPCs are generated the set ID will be 1000NX + NY.

(4) If b = 1, SEQGP cards may be included in the Bulk Data.

NASTRAN DATA DECK


```
ID INPUT, CASE3
TIME 30
APP DISP
SØL 1,3
ALTER 1
PARAM //C,N,NØP/V,N,TRUE=-1 $
INPUT, ,,,,/G1,G2,,G4,/C,N,3/C,N,1 $
EQUIV G1,GEØM1/TRUE  /  G2,GEØM2/TRUE  /  G4,GEØM4/TRUE  $
ENDALTER
CEND
ECHØ=BØTH
TITLE=TEST ØF UTILITY MØDULE INPUT
SUBTITLE=RECTANGULAR PLATE MADE FRØM CQUAD1'S
LABEL=STATICS             SIMPLE SUPPØRTS        REGULAR BAND
SPC=5005
LØAD=1
ØUTPUT
DISP=ALL
BEGIN BULK
FØRCE   1       1       0       1.0     0.0     0.0     1.0
MAT1    7       1.0     1.0
PQUAD1  101     7       1.0     7       2.0     7       4.0
ENDDATA
        5       5       10.0    10.0    126     0.0
        246     156     12356   12346   0       0
```



SPC SET ID IS GIVEN BY 1000 · W + L

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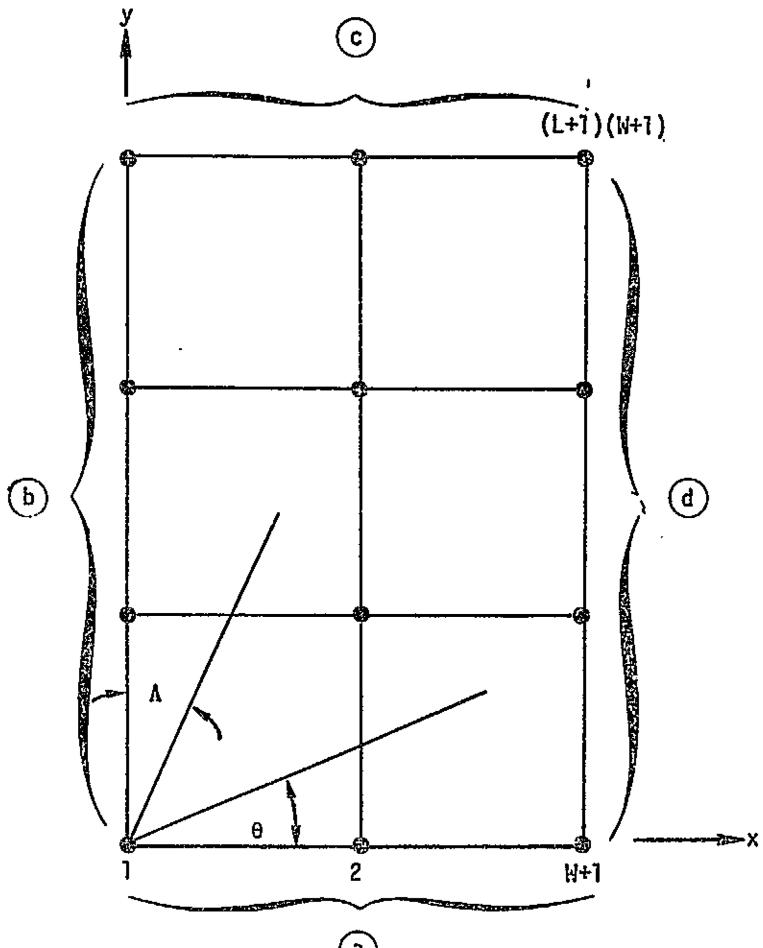
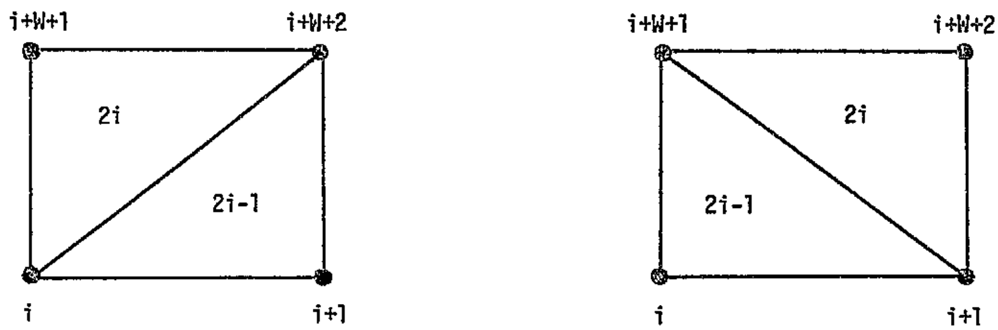
2.6.1.4 Rectangular Plate made from TRIA1s (a=4, b=1,2,3 or 4, c is not used)

INPUT generates GRID, CTRIA1, SEQGP, and SPC (if requested) cards for the rectangular grid work shown.





(c = 1) (c = 2)

a. Data Deck (2 cards required)

<u>First Card</u>

1	W	(18)	No. cells in x-direction
2	L	(18)	No. cells in y-direction
3	Δx	(E8.0)	Length of cell in x-direction
4	Δy	(E8.0)	Length of cell in y-direction
5	IP	(18.0)	Permanent constraints
6	Λ	(E8.0)	Sweep angle in degrees
7	θ	(E8.0)	Material orientation angle in degrees

<u>Second Card</u>

1	IYO	(18)	SPC's on $y = 0$
2	IXO	(18)	SPC's on $x = 0$
3	IYL	(18)	SPC's on $y = L \cdot \Delta y$
4	IXW	(18)	SPC's on $x = W \cdot \Delta x$

b. Options (SEQGP cards)

$$b \begin{cases} =1, \text{ Regular banding (no SEQGP cards generated)} \\ =2, \text{ Double banding} \\ =3, \text{ Active banding} \\ =4, \text{ Reverse double banding} \end{cases}$$

c. Notes

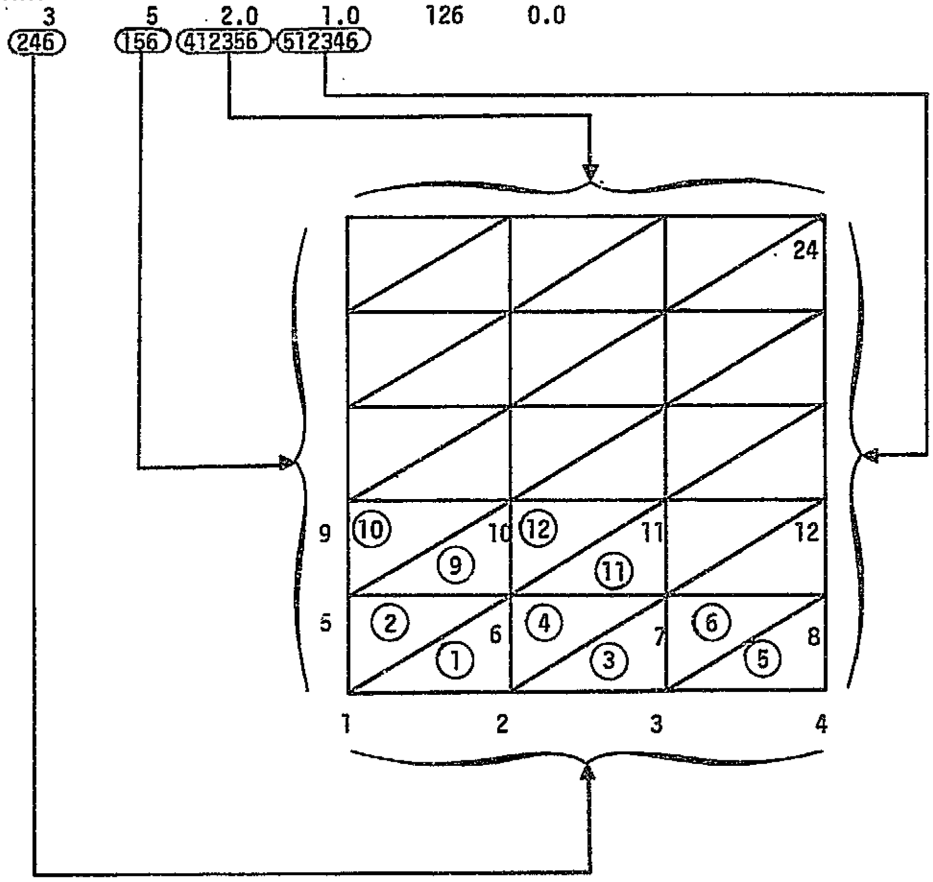
(1) If IP, IYO, IXO, IYL and IXW are all zero, G4 will be purged.

(2) A PTRIA1 card with PID=101 must be included in the Bulk Data.

(3) If SPCs are generated the set ID will be 1000NX + NY.

(4) If b=1, SEQGP cards may be included in the Bulk Data.

```
ID INPUT, CASE 4
TIME 30
APP DISP
SØL 1,3
ALTER 1
PARAM //C,N,NØP/V,N,TRUE=-1 $
INPUT, ,,,,/G1,G2,,G4,/C,N,4/C,N,1/C,N,1 $
EQUIV G1,GEØM1/TRUE  /  G2,GEØM2/TRUE  /  G4,GEØM4/TRUE  $
ENDALTER
CEND
ECHØ=BØTH
TITLE=TEST ØF UTILITY MØDULE INPUT
SUBTITLE=RECTANGULAR PLATE MADE FRØM CTRIA1'S
LABEL=ØPTIØN 1                WITH CLAMPED SUPPØRTS
SPC=3005
LØAD=1
ØUTPUT
DISP=ALL
BEGIN BULK
FØRCE   1       1       0       1.0     0.0     0.0     1.0
MAT1    7       1.0     1.0
PTRIA1  101     7       1.0     7       2.0     7       4.0
ENDDATA
        3       5       2.0     1.0     126     0.0
```



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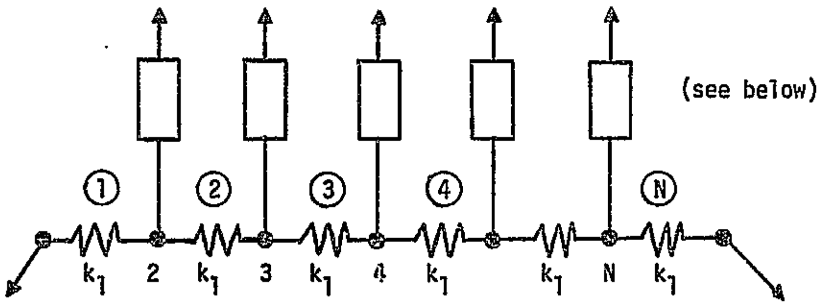
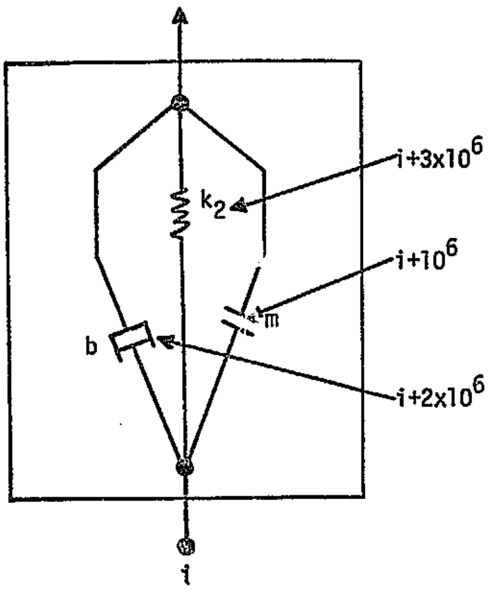
2.6.1.5 N-segment string (a=5, b and c are not used)

INPUT generates CELAS4, CMASS4 and CDAMP4 cards for an N-segment string grounded at both ends.





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USER GENERATED INPUT

a. Data Card

1	N	(I8)	No. of segments
2	k_1	(E8.0)	Spring value
3	k_2	(E8.0)	Spring value (if zero, none of these elements are generated)
4	m	(E8.0)	Mass value (if zero, none of these elements are generated)
5	b	(E8.0)	Damper values (if zero, none of these elements are generated)

b. Notes

(1) If any of k_2, m, or b are zero, those elements will not be generated.

NASTRAN DATA DECK

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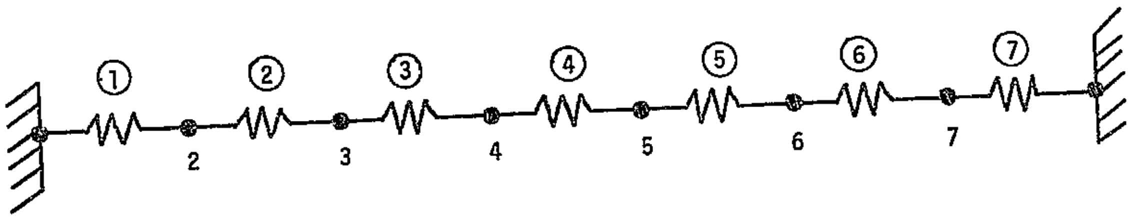
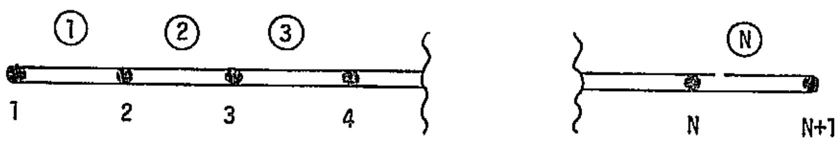
```
ID INPUT, CASE 5
TIME 30
APP DISP
SØL 1,3
ALTER 1
PARAM //C,N,NØP/V,N,TRUE=-1 $
INPUT, ,,,,/,G2,,,/C,N,5 $
EQUIV G2,GEØM2/TRUE $
ENDALTER
CEND
ECHØ=BØTH
TITLE=TEST ØF UTILITY MØDULE INPUT
SUBTITLE=N-SEGMENT STRING
LABEL=STATICS
LØAD=1
ØUTPUT
DISP=ALL
BEGIN BULK
SLØAD       1       3     1.0       6     1.0
ENDDATA
       7     1.0     0.0     0.0     0.0
```



2.6.1.6 N-cell Bar (a=6, b and c are not used)

INPUT generates GRID and CBAR cards for an N-cell bar. ØMIT cards will also be created if requested.



a. Data deck

First Card

1	N	(I8)	No. of cells
2	L	(E8.0)	Length of bar
3	IP	(I8)	Permanent constraints
4	IFLG	(I8)	Orientation vector flag
5	IGO	(18)	GO (used only if IFLG = 2)
6	M	(I8)	No. of right-most grid points to be connected to GP2 via bars with PID = 102
7	IØX	(I8)	ØMIT card count

Second Card (Read only if IFLG = 1)

1	X1	(E8.0)	Orientation vector X1 component
2	X2	(E8.0)	Orientation vector X2 component
3	X3	(E8.0)	Orientation vector X3 component

b. Notes

(1) A PBAR card with PID = 101 is required. If M ≠ 0, a PBAR card with PID = 102 is required.

(2) IFLG = 2 option is not allowed for this case.

(3) Do not include G4 in alter packet unless IØX is greater than 0.

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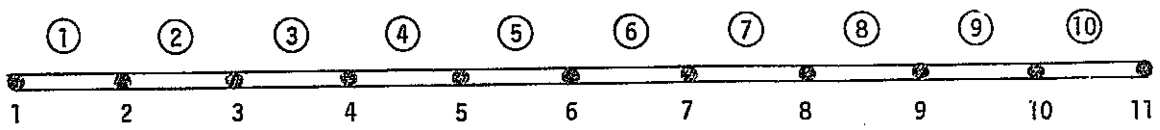
NASTRAN DATA DECK

```
ID INPUT, CASE 6
TIME 30
APP DISP
SØL 1,3
ALTER 1
PARAM //C,N,NØP/V,N,TRUE=-1 $
INPUT, ,,,,/G1,G2,,,/C,N,6 $
EQUIV G1,GEØM1/TRUE  /  G2,GEØM2/TRUE  $
ENDALTER
CEND
ECHØ=BØTH
TITLE=TEST ØF UTILITY MØDULE INPUT
SUBTITLE=N-CELL BAR
LABEL=STATICS
SPC=1
LØAD=1
ØUTPUT
SET 101=11
DISP=101
BEGIN BULK
FØRCE          1      11       0     1.0     0.0     1.0     1.0
MAT1           7     1.0     1.0
PBAR         101       7     1.0     2.0     4.0     8.0
SPC            1       1  123456     0.0
PARAM  GRDPNT  6
ENDDATA
      10   100.0       0       1       0       0       0
     0.0     0.0     1.0
```



2.6.1.7 Full matrix with optional unit load (a=7, b and c are not used)

INPUT generates N scalar points, all of which are interconnected giving N(N+1)/2 elements. On option, SLØAD cards are generated for each CELAS4 scalar point.

a. Data Card

1	N	(I8)	Order of problem	
2	NSLØAD	(I8)	Uniform load flag	=0, will not generate SLØAD cards ≠0, will generate SLØAD cards

b. Notes

(a) GP1 is altered as shown in the example in order to run efficiently.

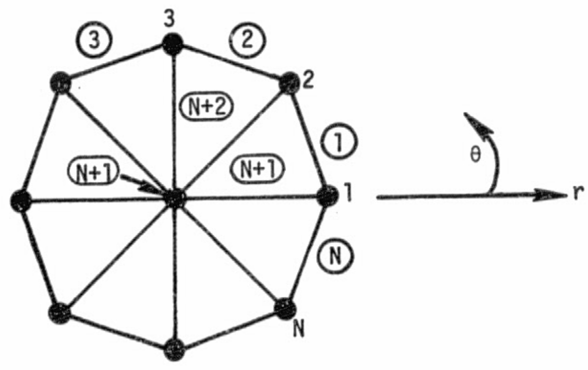
(b) If SLØAD cards are generated the load set ID is N.

NASTRAN DATA DECK

```
ID INPUT, CASE 7
TIME 30
APP DISP
SØL 1,3
ALTER 1
PARAM //C,N,NØP/V,N,TRUE=-1 $
INPUT, ,,,,/,G2,G3,,G5/C,N,7 $
EQUIV G2,GEØM2/TRUE  /  G3,GEØM3/TRUE  $
ALTER 4,4
GP1 GEØM1,G5/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/V,N,LUSET/C,N,0/V,N,NØGPDT $
ENDALTER
CEND
ECHØ=BØTH
TITLE=TEST ØF UTILITY MØDULE INPUT
SUBTITLE=FULL MATRIX WITH ØPTIØNAL UNIT LØAD
LABEL=ØRDER = 10
LØAD=10
ØUTPUT
DISP=ALL
SPCF=ALL
ØLØAD=ALL
ELFØ=ALL
BEGIN BULK
{blank card}
ENDDATA
      10    1
```

2.6.1.8 N - spoked Wheel made from BAR elements (a = 8, b and c are not used)

INPUT generates N+1 GRID points, all of which are connected to the last point, and N CBAR cards. The CBAR cards represent connections around the circumference and spokes in the wheel as shown.



a. Data deck

First Card

1	N	(I8)	No. of spokes
2	XL	(E8.0)	Radius of wheel
3	IP	(I8)	Permanent constraints on rim
4	IFLG	(I8)	Orientation vector flag
5	IGO	(I8)	GO (used only if IFLG = 2)
6	ICEN	(I8)	Permanent constraints at center

Second Card

1	X1	(E8.0)	Orientation vector X1 component
2	X2	(E8.0)	Orientation vector X2 component
3	X3	(E8.0)	Orientation vector X3 component

b. Notes

(1) A PBAR card with PID = 101 is required.

(2) The option, IFLG = 2, is not allowed for this case.

(3) A coordinate system with CID = 2 is required. All points, except the center, will reference this system.

(4) The number of spokes, N, cannot exceed 255.

NASTRAN DATA DECK


```
ID INPUT, CASE 8
TIME 10
APP DISP
SØL 1,3
ALTER 1
PARAM //C,N,NØP/V,N,TRUE=-1 $
INPUT GEØM1,GEØM2,,,/G1,G2,,,/C,N,8 $
EQUIV G1,GEØM1/TRUE / G2,GEØM2/TRUE $
ENDALTER
CEND
TITLE = TEST ØF UTILITY MØDULE INPUT
SUBTITLE = N-SPØKED WHEEL
LABEL = STATICS
LØAD = 20
ØUTPUT
DISP = ALL
BEGIN BULK
CØRD2C   2       0       0.0     0.0     0.0     1.0     0.0     0.0     +CYL
+CYL     0.0     0.0     1.0
FØRCE    20      1       0       1.0     1.0     0.0     0.0
MAT1     7       1.0             0.3
PBAR     101     7       1.0     100.0   100.0
ENDDATA
        8     10.0    12456         1         0   123456
     0.0      0.0       1.0
```

2.7 SUBSTRUCTURE CONTROL DECK

The Substructure Control Deck options provide the user commands needed to control the execution of NASTRAN for automated multi-stage substructure analyses. These commands are input on cards with the same format conventions as are used for the normal NASTRAN Case Control Deck.

Initiation of a substructure analysis is achieved via the Executive Control Deck command (see Section 2.1):

APP DISPLACEMENT,SUBS

This command directs NASTRAN to automatically generate the required DMAP sequence of alters to the specified Rigid Format necessary to perform the operations requested in the Substructure Control Deck. Following the Substructure Control Deck in the NASTRAN input data stream comes the standard Case Control Deck which specifies the loading conditions, omit sets, method of eigenvalue extraction, element sets for plotting, plot control, and output requests, etc.

The Substructure Control Deck commands are summarized in Table 1 where they are listed under one of three categories according to whether they:

1. Specify the phase and mode of execution
2. Specify the substructuring matrix operations
3. Define and control the substructure operating file (SØF)

Several commands have associated with them a set of subcommands used to specify additional control information appropriate to the processing requested by the primary command. These subcommands are defined together with the alphabetically sorted descriptions of their primary commands in Section 2.7.3. Examples utilizing these commands are presented in Section 1.

The sections that follow discuss the interaction between the substructure commands and the standard case control commands, the translation of substructure commands into DMAP ALTER sequences, and the format conventions to be used. The bulk data cards provided for substructure analyses are included with the standard bulk data descriptions in Section 2.3 and they are summarized for convenient reference in Table 2.

Table 1. Summary of Substructure Commands

A. Phase and Mode Control	
#SUBSTRUCTURE	- Defines execution phase (1, 2, or 3) (Required)
NAME*	- Specifies Phase 1 substructure name
SAVEPLØT	- Requests plot data be saved in Phase 1
ØPTIØNS	- Defines matrix options (K, B, K4, M, P, or PA)
RUN	- Limits mode of execution (DRY, GØ, DRYGØ, STEP)
#ENDSUBS	- Terminates Substructure Control Deck (Required)
B. SØF Controls	
#SØF	- Assigns physical files for storage of the SØF (Required)
PASSWØRD*	- Protects and ensures access to correct file
SØFØUT or SØFIN	- Copies SØF data to or from an external file
PØSITIØN	- Specifies initial position of input file
NAMES	- Specifies substructure name used for input
ITEMS	- Specifies data items to be copies in or out
SØFPRINT	- Prints selected items from the SØF
DUMP	- Dumps entire SØF to a backup file
RESTØRE	- Restores entire SØF from a previous DUMP operation
CHECK	- Checks contents of external file created by SØFØUT
DELETE	- Edits out selected groups of items from the SØF
EDIT	- Edits out selected groups of items from the SØF
DESTRØY	- Destroys all data for a named substructure and all the substructures of which it is a component
C. Substructure Operations	
CØMBINE	- Combines sets of substructures
NAME*	- Names the resulting substructure
TØLERANCE*	- Limits distance between automatically connected grids
CØNNECT	- Defines sets for manually connected grids and releases
ØUTPUT	- Specifies optional output results
CØMPØNENT	- Identifies component substructure for special processing
TRANSFØRM	- Defines transformations for named compoennt substurctures
SYMTRANSFØRM	- Specifies symmetry transformation
SEARCH	- Limits search for automatic connects
EQUIV	- Creates a new equivalent substructure
PREFIX*	- Prefix to rename equivalenced lower level substructures

Mandatory Control Cards   * Required Subcommand

(Continued)

Table 1. Summary of Substructure Commands (continued)

C. Substructure Operations (continued)	
REDUCE	- Reduces substructure matrices
NAME*	- Names the resulting substructure
BØUNDARY*	- Defines set of retained degrees of freedom
ØUTPUT	- Specifies optional output requests
RSAVE	- Save REDUCE decomposition product
MREDUCE	- Reduces substructure matrices
NAME*	- Names the resulting substructure
BØUNDARY*	- Defines set of retained degrees of freedom
FIXED	- Defines set of constrained degrees of freedom for modes calculation
RNAME	- Specifies basic substructure to define reference point for inertia relief shapes
RGRID	- Specifies grid point in the basic substructure to define reference point for inertia relief shapes. Defaults to origin of basic substructure coordinate system
METHØD	- Identifies EIGR Bulk Data card
RANGE	- Identifies frequency range for retained modal coordinates
NMAX	- Identifies number of lowest frequency modes for retained modal coordinates
ØLDMØDES	- Flag to identify rerunning problem with previously computed modal data
ØLDBØUND	- Flag to identify rerunning problem with previously defined boundary set
USERMØDES	- Flag to indicate modal data have been input on bulk data
ØUTPUT	- Specifies optional output requests
RSAVE	- Indicates the decomposition product of the interior point stiffness matrix is to be stored on the SØF
CREDUCE	- Reduces substructure matrices using a complex modes transformation
NAME*	- Names the resulting substructure
BØUNDARY	- Defines set of retained degrees of freedom
FIXED	- Defines set of constrained degrees of freedom for modes calculation
METHØD	- Identifies EIGC Bulk Data card
RANGE	- Identifies frequency range of imaginary part of the root for retained modal coordinates
NMAX	- Identifies number of lowest frequency modes for retained modal coordinates
ØLDMØDES	- Flag to identify rerunning problem with previously computed modal data
RSAVE	- Indicates the decomposition product of the interior point stiffness matrix is to be stored on the SØF
MRECØVER	- Recovers mode shape data from an MREDUCE or CREDUCE operation
SAVE	- Stores modal data on SØF
PRINT	- Stores modal data and prints data requested
SØLVE	- Initiates substructure solution (statics, normal modes, frequency response or transient analysis)

(Continued)

* Required Subcommand

Table 1. Summary of Substructure Commands (continued).

C. Substructure Operations (continued)	
RECØVER	- Recovers Phase 2 solution data
SAVE	- Stores solution data on SØF
PRINT	- Stores solution and prints data requested
DISP	- Displacement output request
SPCF	- Reaction force output request
ØLØAD	- Applied load output request
VELØ	- Velocity output requests
ACCE	- Acceleration output requests
BASIC	- Basic substructure for output requests
SØRT	- Output sort order
SUBCASES	- Subcase output request
MØDES	- Modes output request
RANGE	- Mode range output request
ENERGY	- Modal energies output requests
UIMPROVE	- Improved displacement request
STEPS	- Frequency or time step output request
BRECØVER	- Basic Substructure data recovery, Phase 3
PLØT	- Initiates substructure undeformed plots

* Required Subcommand

Table 2. Substructure Bulk Data Card Summary.

A. Bulk Data Used for Processing Substructure Commands REDUCE, MREDUCE, and CREDUCE	
BDYC	- Combination of substructure boundary sets of retained degrees of freedom or fixed degrees of freedom for modes calculation
BDYS	- Boundary set definition
BDYS1	- Alternate boundary set definition
B. Bulk Data Used for Processing Substructure Command CØMBINE	
CØNCT	- Specifies grid points and degrees of freedom for manually specified connectivities - will be overridden by RELES data
CØNCT1	- Alternate specification of connectivities
RELES	- Specifies grid point degrees of freedom to be disconnected - overrides CØNCT and automatic connectivities
GTRAN	- Redefines the output coordinate system grid point displacement sets
TRANS	- Specifies coordinate systems for substructure and grid point transformations
C. Bulk Data used for Processing Substructure Command SØLVE	
LØADC	- Defines loading conditions for static analysis
MPCS	- Specifies multipoint constraints
SPCS	- Specifies single point constraints
SPCS1	- Alternate specification of single point constraints
SPCSD	- Specifies enforced displacements for single point constraints
DAREAS	- Defines dynamic load scale factors
DELAYS	- Defines dynamic load time delays
DPHASES	- Defines dynamic load Phase leads
TICS	- Defines transient initial conditions

2.7.1 Commands and Their Execution

The sequence of operations is controlled by the order in which NASTRAN encounters the substructure commands. A few special data cards are required in any Substructure Command Deck. These are:

SUBSTRUCTURE $\begin{Bmatrix} \text{PHASE1} \\ \text{PHASE2} \\ \text{PHASE3} \end{Bmatrix}$ - The first card of the Substructure Command Deck and it follows the CEND card of the Executive Control Deck.

SØF / PASSWØRD - Required to define the substructure operating file to be used for this execution.

ENDSUBS - Signals the end of the Substructure Command Deck.

The first step of any substructuring analysis is to define the basic substructures to be used. These are prepared by executing one Phase 1 run for each substructure. Checkpoints may be taken for each Phase 1 execution to save the files to be used during the Phase 3 data recovery runs. Alternately, the user may resubmit his entire original data deck for a Phase 3 run, thereby avoiding a proliferation of checkpoint tapes. During a Phase 2 execution, a long list of instructions may be specified. This list may be split up and run in several separate smaller steps. No checkpointing is required during a Phase 2 run in that all pertinent substructure data will be retained on the substructure operating file (SØF).

The Case Control Deck submitted following the ENDSUBS card will be used to direct the processing appropriate to the particular Phase being executed. During a Phase 1 run, the Case Control will be used to define the loading conditions, single and multipoint constraints (only one set may be used per basic substructure), omits, and desired plot sets. During a Phase 2 run, the Case Control will be used to specify the loads and constraint data for the SØLVE operation, outputting of results, or any plot requests. Finally, for a Phase 3 execution, the Case Control Deck is used to define the detail output and plot requests for each basic substructure.

Normal substructuring analyses will require many steps to be executed under Phase 2 processing. They may all be submitted for processing at once, or they may be divided into several shorter sequences and executed separately. In the event of an abnormal termination, several steps may have been successfully executed. To recover requires simply removing those completed steps from the Substructure Control Deck and resubmitting the remaining commands. The SØF will act as the checkpoint/restart file independently of the normal NASTRAN checkpointing procedures.

If the solution structure is large, a NASTRAN checkpoint would be recommended to save intermediate results during the SØLVE operation. If this is done, however, care must be exercised on restart to insure correct re-entry into the DMAP sequence. This may be accomplished by removing all substructure control commands preceding the SØLVE, modifying the Case Control Deck and Bulk Data Deck to change set identifiers only if any new loads or constraint sets are to be specified and resubmitting the job. If no changes are to be made which would affect the SØLVE operations, a regular restart can be executed without changing the original Case Control and Bulk Data Decks.

The user may wish to add to or modify the DMAP sequence generated automatically from the Substructure Control Deck commands. This user interaction with the DMAP operations is explained in the following section.

2.7.2 Interface with NASTRAN DMAP

Each substructure command card produces a set of DMAP ALTER cards which are automatically inserted into the Rigid Format called for execution on the SØL card of the Execution Control Deck (Section 2.2). These automatically generated alters require no user interfacing unless the user wishes to exercise the following options:

1. The user may insert ALTER cards in the Executive Control Deck. However, they may not overlap any DMAP cards affected by the substructure ALTERs. The DMAP card numbers, modified for each Rigid Format, are given in Sections 3.2, 3.3, 3.4, 3.9 and 3.10.

2. The user may suppress the DMAP generated by the substructure deck and run with either ALTER cards or with approach DMAP. To suppress the automatic DMAP, the following forms of the executive control card APP are provided

   APP DISP,SUBS,1 (Retains execution of the substructuring preface operations)

   or APP DMAP (Standard NASTRAN is executed)

3. For user information and convenience, the substructure ALTER packages may be printed and/or punched on cards. The executive control card, DIAG 23, will produce the printout. DIAG 24 will produce the punched deck. The punched deck may then be altered by the user and resubmitted as described in (2) above. However, the order of the associated substructure command deck must not be changed to insure proper sequencing of the requested operations.

2.7.3 Substructure Control Card Descriptions

The format of the substructure control cards is free-field. In presenting general formats for each card embodying all options, the following conventions are used:

1. Upper-case letters must be punched as shown.
2. Lower-case letters indicate that a substitution must be made.
3. Braces { } indicate that a choice of contents is mandatory.
4. Brackets [ ] contain an option that may be omitted or included by the user.
5. Underlined options or values are the default values.
6. Physical card consists of information punched in columns 1 thru 72 of a card. All Substructure Control Cards are limited to a single physical card.

The Case Control Deck, which follows the ENDSUBS card of the Substructure Control Deck is described in Section 2.3.

Substructure Command BRECØVER - Basic Substructure Data Recovery

Purpose: This operation is performed in Phase 3 to recover detailed output data for a basic substructure used in Phase 1.

Request Format:

BRECØVER name

Subcommands: None

Definitions:

name - Name of structure defined in Phase 1 or structure equivalenced to the Phase 1 structure.

Notes: 1. Use of the RECØVER command in Phase 3 has the same effect as BRECØVER. That is, RECØVER is an alias for BRECØVER in Phase 3.

2. Phase 3 may be a RESTART of the original Phase 1 run or it may be executed from the original input data.

Substructure Command CHECK - Check Contents of External File

Purpose: To list all substructure items on an external file which was generated with SØFØUT.

Request Format:

CHECK filename $\left\{\begin{array}{l}\text{DISK} \\ \text{,\underline{TAPE}}\end{array}\right\}$

Subcommands: None

Definitions:

filename - Name of the external file. One of the following: INPT, INP1,..., INP9.

DISK - File resides on a direct access device.

TAPE - File resides on tape.

Notes: 1. The substructure name, item name, and the date and time the item was written are listed for each item on the file.

Substructure Command CØMBINE - Combine Sets of Substructures

Purpose: This operation will perform the operations to combine the matrices and loads up to seven substructures into matrices and loads representing a new pseudostructure. Each component structure may be translated, rotated, and reflected before it is connected. The user may manually select the points to be connected or direct the program to connect them automatically.

Request Format:

$$\text{CØMBINE}\left(\left\{\frac{\text{AUTØ}}{\text{MAN}}\right\},\left\{\begin{matrix}X\\Y\\Z\end{matrix}\right\}\right)\quad \text{name1, name2, etc.}$$

Subcommands:

NAME = new name (required)
TØLERANCE = ε (required)
CØNNECT = n
ØUTPUT = m_1, m_2,...

Each individual component substructure may have the following added commands:

$$\left.\begin{array}{l}\text{CØMPØNENT} = \text{name}\\ \text{TRANSFØRM} = m\\ \text{SYMTRANSFØRM} = \left\{\begin{matrix}X\\Y\\Z\\XY\\XZ\\YZ\\XYZ\end{matrix}\right\}\\ \text{SEARCH} = \text{namej, namek, etc.}\end{array}\right\}\begin{array}{c}\text{repeat}\\ \text{for each}\\ \text{component}\end{array}$$

Definitions:

AUTØ/MAN - Defines method of connecting points. If AUTØ is chosen, the physical location of grid points is used to determine connections. If MAN, all connections are defined on CØNCT or CØNCT1 bulk data.

X, Y, Z - Are used on CØMBINE card for searching geometry data for AUTØ connections. Denotes preferred search direction for processing efficiency.

name1, name2, etc. - Unique names of substructures to be combined. Limits are from one to seven component structures.

new name - Defines name of combination structure (required).

ε - Defines limit of distance between points which will be automatically connected (real > 0).

n - Defines set number of manual connections and releases specified on bulk data cards, CØNCT, CØNCT1, and RELES.

name - On CØMPØNENT card defines which substructure (name1, etc.) to which the following data is applied.

(Continued)

m - Set identification number of TRANS and GTRAN bulk data cards which define the orientation of the substructure and/or selected grid points relative to new basic coordinates.

X,Y,...XY,...XYZ - Defines axis (or set of axes) <u>normal</u> to the plane(s) of symmetry in the new basic coordinate system. The displacement and location coordinates in these directions will be reversed in sign.

namej - Limits the automatic connection process such that only connections between component "name" and these structures are produced. Multiple search commands may appear for any one component (see Note 4).

m_1, m_2, etc. - Optional output requests (see Note 5).

Notes:

1. The automatic connections are produced by first sorting the grid point coordinates in the specified coordinate direction and then searching within limited groups of coordinates. If the boundary of a substructure to be connected is aligned primarily along one of the coordinate axes, this axis should be used as the preferred search direction. If the boundary is parallel with, say, the yz plane and all boundary coordinates have a constant x value, then the search should be specified along either the y or the z axis.

2. The transformation (TRANS) data defines the orientation of the component substructure (old basic) in terms of the new basic coordinate system. All grid points originally defined in the old basic system will be transformed to the new basic system. Points defined in local coordinate systems will not be transformed unless otherwise specified on a GTRAN card, and their directions will rotate with the substructure.

3. The SYMTRANFØRM (or SYMT) request is primarily used to produce symmetric reflections of a structure. This is usually preceded by an EQUIV command to produce a new, unique substructure name. Note that the results for the new reflected substructure may reference a left-handed coordinate system wherever local coordinate systems are retained during the transformation. However, those coordinates which are originally in the old basic or are newly specified via a GTRAN card are automatically transformed to a right-handed coordinate system of the combined structure during the combination process. Note that the symmetric reflection occurs first using the component's own basic coordinate system before the translational and rotational transformation called for by TRANS.

4. If any search option is present then all connections between substructures must be specified explicitly with SEARCH commands. Only those combinations specified will be searched for possible connects. Symmetric connects need not be declared (i.e., CØMPØNENT A SEARCH B implies CØMPØNENT B SEARCH A). The user is warned that care must be taken to assure all proper connections of substructures should any SEARCH commands be utilized.

5. The program automatically processes matrix data for the CØMBINE operation in the most economical order, i.e., the matrices with fewest terms are processed first.

6. The bandwidth of the resultant matrices may be controlled by selection of substructures, their boundaries, and the order in which the substructures are listed in the CØMBINE command. The degrees of freedom in the resultant matrices are located as defined in the sample problem below:

CØMBINE A, B, C, D

A	interior	ABC	boundary
AB	boundary	C	interior
B	interior	AD	boundary
AC	boundary	BD	boundary
BC	boundary	Etc.	

(Continued)

7. The following output requests are available for the CØMBINE operation (* marks recommended output options):

CODE	OUTPUT	
2*	SØF table of contents	
3	CØNCT1 bulk data summary	
4	CØNCT bulk data summary	
6	GTRAN bulk data summary	
7*	TRANS bulk data summary	
9	RELES bulk data summary	
11	Summary of automatically-generated connections (in terms of internal point numbers)	
12*	Complete connectivity map of final combined pseudostructure defining each internal point in terms of the grid point ID and component substructure it represents	
13	The EQSS item	Output printed is formatted SØF data for the newly created pseudostructure (See Section 1.10.2 for definitions).
14	The BGSS item	
15	The CSTM item	
16	The PLTS item	
17	The LØDS item	

Examples:

1. CØMBINE PANEL SPAR

```
TØLE = .0001
NAME = SECTA
```

2. CØMBINE (AUTØ,Z) TANK1, TANK2, BULKHD

```
NAME = TANKS
TØLE = .01
CØMPØNENT TANK1
TRAN = 4
SEARCH = BULKHD
CØMPØNENT TANK2
SEARCH = BULKHD
```

3. CØMBINE (MAN) LWING, RWING

```
TØLE = 1.0
NAME = WING
CØMPØNENT LWING
SYMT = Y
```

Substructure Command CREDUCE - Reduces Substructure Matrices Using Complex Modes

Purpose: This operation performs a complex modal synthesis reduction on a specified component substructure. The resulting substructure will be defined by boundary point displacements and modal displacements as degrees of freedom. The operation is allowed in both Phase 1 and Phase 2 jobs and may be performed at any level of the substructure process.

Request Format:

CREDUCE name

Subcommands:

NAME - new name

BØUNDARY - b

FIXED - f

METHØD - k

RANGE - f_1, f_2

NMAX - N

ØUTPUT - m_1, m_2

ØLDMØDES - m

GPARAM - g

RSAVE

Definitions:

name - Name of substructure to be reduced

new name - Name of resulting substructure

b - Set identification number of bDYC Bulk Data cards which define sets of boundary degrees of freedom (Integer > 0)

f - Optionally identifies BDYC data defining degrees of freedom temporarily fixed during mode extraction (Integer $\geq$ 0, Default = 0)

k - Identifies EIGC Bulk Data card for control of the eigenvalue extraction (Integer > 0)

f_1, f_2 - Optional frequency range (H_z) for the imaginary part of the root defining eigenvectors to be used in the mode synthesis formulation (Real, Default = ALL)

NMAX - Optional number of lowest modes, measured by magnitude of eigenvalue, within frequency range to be used in mode synthesis formulation (Integer, Default = ALL)

m_1, m_2 - Optional output requests (see Note 2)

m - Flag for rerunning problem with old eigenvectors (YES or NØ)

g - Structure damping parameter (real)

(Continued)

Notes: 1. All references to the grid points and components not defined in the "boundary set" will be reduced out of the new substructure. Any subsequent reference to these omitted degrees of freedom in CØMBINE, CREDUCE, MREDUCE, REDUCE, or SØLVE operations generates an error condition.

2. The following output requests are available for the CREDUCE operation (* marks recommended output options):

Code	Output	
1*	Current problem summary	
2	Boundary set summary	
3	Summary of grid point ID numbers in each boundary set	
4	The EQSS item for the structure being reduced	
5*	The EQSS item	These requests write formatted SØF items for the new reduced pseudostructure
6*	The BGSS item	
7	The CSTM item	
8	The PLTS item	
9*	The LØDS	
10*	Modal dof set summary	
11	Fixed set summary	
12	Summary of grid point ID numbers in each fixed set	

3. The ØLDMØDES option instructs the program to use the existing modal data but create new boundary matrices for a new boundary set. To exercise the ØLDMØDES option, the user must use the following sequence of commands to eliminate previously calculated boundary point data:

```
EDIT(32) new name (previous modal reduction name)

DELETE name, GIMS, LMTX, HLFT, HØRG, UPRT

DELETE name, PØVE, PØAP

CREDUCE name
   .
   .
   .
```

4. If the RSAVE card is included, the decomposition product of the interior point stiffness matrix (LMTX item) is saved on the SØF file. This matrix will be used in the data recovery for the omitted points. If it is not saved it will be regenerated when needed.

Substructure Command DELETE

Purpose: To delete individual substructure items from the SØF.

Request Format:

DELETE name, item1, item2, item3, item4, item5

Subcommands: None

Definitions:

name - Substructure name

item1, item2,... - Item names (HØRG, KMTR, LØDS, SØLN, etc.)

Notes:
1. DELETE may be used to remove from one to five items of any single substructure.
2. For primary substructures, items of related secondary substructures are removed only if the later point to the same data (KMTX, MMTX, etc.).
3. For secondary and image substructures, no action is taken on items of related substructures, i.e., items of equivalenced substructures or higher or lower level substructures.
4. See the EDIT and DESTRØY commands for other means of removing substructure data.

Substructure Command DESTRØY - Removes All Data Referencing a Component Substructure

Purpose: To remove data for a substructure and all substructures of which it is a component from the SØF. In addition to the substructure being DESTRØY'ed ("name"), data for substructures which satisfy one or more of the following conditions are also removed from the SØF:

1. All substructures of which "name" is a component

2. All secondary (or equivalenced) substructures for which "name" is the primary substructure

3. All image substructures which are components of a substructure that is destroyed

Request Format:

DESTRØY name

Subcommands: None

Definition:

name - Name of substructure

Notes: 1. No action is taken if "name" is an image substructure.

2. See related commands EDIT and DELETE for additional means of removing substructure data.

Substructure Command DUMP

Purpose: To copy the entire SØF to an external file.

Request Format:

DUMP filename $\left\{ \begin{matrix} \text{DISK} \\ ,\underline{\text{TAPE}} \end{matrix} \right\}$

Subcommands: None

Definitions:

Filename - Name of the external file. Any one of the following: INPT, INP1,..., INP9.

DISK - File resides on a direct access device.

TAPE - File resides on tape.

Notes:

1. DUMP may be used to create a backup copy of the SØF.
2. All system information on the SØF is saved.
3. The RESTØRE command will reload a DUMPed SØF.
4. DUMP/RESTØRE may not be used to change the size of the SØF.
5. It is more efficient to use operating system utility programs to create back-up copies of the SØF if they are available.

Substructure Command EDIT - Selectively Removes Data from SØF File

Purpose: To permanently remove selected substructure data from the SØF.

Request Format:

EDIT (opt) name

Subcommands: None

Definitions:

name - Name of substructure.

opt - Integer value reflecting combinations of requests. The sum of the following integers defines the combination of data items to be removed from the SØF.

ØPT	Items Removed
1	Stiffness matrix (KMTX)
2	Mass matrix (MMTX)
4	Load data (LØDS, LØAP, PVEC, PAPP)
8	Solution data (UVEC, QVEC, SØLN)
16	Transformation matrices defining next level (HØRG, UPRT, PØVE, PØAP, LMTX, GIMS, HLFT)
32	All items for the substructure
64	Appended loads data (LØAP, PAPP, PØAP)
128	Damping matrices (K4MX, BMTX)
256	Modal reduction data (LAMS, PHIS, PHIL)
512	Total transforms only (HØRG, HLFT)

Notes:

1. The user is cautioned on the removal of the transformation matrix data. These matrices are required for the recovery of the solution results.
2. For primary substructures, items of related secondary substructures are removed only if they point to the same data (KMTX, MMTX, etc.)
3. For secondary and image substructures, no action is taken on items of related substructures, i.e., items of equivalenced or higher or lower level substructures.
4. If the EDIT feature is to be employed, the user should consider also using SØFØUT to ensure the existence of backup data in the event of an error.
5. See DELETE and DESTRØY for other means of removing substructure data.

Substructure Command <u>ENDSUBS</u> - Defines the End of the Substructure Control Deck.

<u>Purpose</u>: This command terminates the processing of automated substructuring controls and directives.

<u>Request Format</u>:

ENDSUBS

<u>Subcommands</u>:

None

Substructure Command EQUIV - Create a New Equivalent Substructure

Purpose: To assign an alias to an existing substructure and thereby create a new equivalent substructure. The new secondary substructure may be referenced independently of the original primary substructure in subsequent substructure commands. However, the data actually used in substructuring operations is that of the primary substructure.

Request Format:

EQUIV name1, name2

Subcommands:

PREFIX = p

Definitions:

p - Single BCD character.

name1 - Existing primary substructure name.

name2 - New equivalent substructure name.

Notes:
1. A substructure created by this command is referred to as a secondary substructure.
2. All substructures which were used to produce the primary substructure will produce equivalent image substructures. The new image substructure names will have the prefix p.
3. A DESTRØY operation on the primary substructure data will also destroy the secondary substructure data and all image substructures.
4. An EDIT or DELETE opeartion on the primary substructure will not remove data of the secondary substructure and vice versa.

Substructure Command <u>MRECØVER</u> - Eigenvector Recovery for Modal Synthesis Operations

<u>Purpose</u>: This operation recovers modal displacements and boundary forces for substructures reduced to modal coordinates. The results are saved on the SØF file and they may be printed upon user request. This command may be input after the MREDUCE or CREDUCE commands or at a later time as desired.

<u>Request Format:</u>

RECØVER s-name

<u>Subcommands:</u>

SAVE - name

PRINT - name

DISP - $\left\{\begin{array}{c}\text{ALL}\\ \text{n}\\ \underline{\text{NØNE}}\end{array}\right\}$

SPCF - $\left\{\begin{array}{c}\text{ALL}\\ \text{n}\\ \underline{\text{NØNE}}\end{array}\right\}$

BASIC - b-name

ENERGY - $\left\{\begin{array}{c}\text{ALL}\\ \text{n}\\ \underline{\text{NØNE}}\end{array}\right\}$

SØRT - $\left\{\begin{array}{l}\underline{\text{MØDES}}\\ \text{SUBSTRUCTURE}\end{array}\right\}$

MODES - $\left\{\begin{array}{c}\underline{\text{ALL}}\\ \text{n}\\ \text{NØNE}\end{array}\right\}$

RANGE - f_1, f_2

UIMPRØVE

<u>Definitions:</u>

s-name - Name of the resulting substructure named in a prior MREDUCE or CREDUCE command from which the solution results are to be recovered.

name - Name of the component structure for which results are to be recovered. May be the same as "s-name"

b-name - Name of component basic substructure that following output requests are to apply

ALL - Øutput for all points will be produced.

NØNE - No output is to be produced.

n - Set identification number of a SET card appearing in Case Control. Only output for those points whose identification number appears on this SET card will be produced.

(Continued)

f_1, f_2 - Range of frequencies for which output will be produced. If only f_1 is present the range is assumed to be $0 - f_1$.

MØDES - All output requests for each mode will appear together.

SUBSTRUCTURE - All output requests for each basic substructure will appear together.

Output Requests: Printed output produced by the MRECØVER PRINT command can be controlled by requests present in either Case Control or the MRECØVER command in the Substructure Control Deck. If no output requests are present, the PRINT command is equivalent to SAVE and no output will be printed.

The output options described above may appear after any PRINT command. These output requests will then override any Case Control requests. The output requests for any PRINT command can also be specified for any or all basic component substructures of the results being recovered. These requests will then override any requests in Case Control or after the PRINT command.

Example of output control:

```
MRECØVER SØLSTRCT
    PRINT   ABSC
        SØRT = SUBSTRUCTURE }  basic defaults for ABDC output
        DISP = ALL          }
        BASIC   A           }  override requests for BASIC A
            DISP = 5        }
        BASIC   C           }  override requests for BASIC C
            SPCF = 20       }
    SAVE   ABC
```

Notes: 1. SAVE will save the solution for substructure "name" on the SØF. PRINT will save and print the solution.

2. If the solution data already exists on the SØF, the existing data can be printed without costs of regeneration with the PRINT command.

3. For efficiency, the user should order multiple SAVE and/or PRINT commands so as to trace one branch at a time starting from his solution structure.

4. Reaction forces are computed for a substructure only if (1) the substructure is named on a PRINT subcommand and, (2) an output request for SPCFØRCE or modal energies exists in the Case Control or the RECØVER command.

5. All set definitions should appear in Case Control to ensure their availability to the MRECØVER module.

6. The SØRT output option should only appear after a PRINT command. Any SØRT commands appearing after a BASIC command will be ignored.

7. If both a MØDES request and a RANGE request appear for dynamic analysis, both requests must be satisfied for any output to be produced.

8. The media, print or punch, where output is produced is controlled through Case Control requests. If no Case Control requests are present, the default of print is used.

9. If the UIMPRØVE request is present for a substructure that was input to a REDUCE, MREDUCE, or CREDUCE, an improved displacement vector will be generated. This vector will contain the effects of inertia and damping forces.

10. The ENERGY request will cause the calculation of modal energies on all included and excluded modal dof for a modal reduced substructure. This request should appear for the substructure that was input to the modal reduce operation so that required data needed for the excluded mode calculations exists. This request requires that the UVEC item exists for the next highest level structure.

(Continued)

MRECØVER (Cont.)

11. The user can specify print thresholds for all printout. If the absolute value is less than the threshold, the value will be set to zero. The following thresholds can be input on PARAM bulk data cards.

    UTHRESH - displacement, velocity and acceleration threshold

    PTHRESH - load threshold

    QTHRESH - reaction force threshold

Substructure Command MREDUCE - Reduces Substructure Matrices Using Real, Normal Modes

Purpose: This operation performs a modal synthesis reduction on a specified component substructure. The resulting substructure will be defined by boundary coordinate displacements and modal coordinate displacements as degrees of freedom. The operation is allowed in both Phase 1 and Phase 2 jobs and may be performed at any level of the substructure process.

Request Format:

MREDUCE name

Subcommands:

NAME - new name

BØUNDARY - b

FIXED - f

METHØD - k

RANGE - f_1, f_2

NMAX - N

RGRID - i

RNAME - c-name

RSAVE

ØLDMØDES - m

ØLDBØUND - n

USERMØDES - j

ØUTPUT - m_1, m_2

Definitions:

name - Name of substructure to be reduced

new name - Name of resulting substructure

b - Set identification number of BDYC Bulk Data cards which define sets of boundary degrees of freedom (Integer).

f - Optionally identifies BDYC data defining degrees of freedom temporarily fixed during mode extraction (Integer, Default = 0).

k - Identifies EIGR Bulk Data card for control of the mode extraction (Integer > 0).

i - Grid point number for defining origin of free body motion. Used with RNAME to define substructure component containing grid point i (Integer $\geq$ 0, Default = 0).

(Continued)

c-name - Name of basic substructure which contains grid point i. If RGRID = 0 or is missing, the origin of the overall basic coordinate system is used to define the six rigid body motions. These motions define the inertia relief deflection shapes which are used as generalized coordinates in addition to the modal coordinates.

m - Flag for rerunning problem with old mode shapes (YES or NØ).

n - Flag for rerunning problem with old boundaries for different eigenvalue method (YES or NØ).

f_1, f_2 - Optional frequency range (H_Z) defining modes to be used in the mode synthesis formulation (Real, Default = ALL).

NMAX - Optional number of lowest modes within frequency range to be used in mode synthesis formulation (Integer, Default = ALL).

j - Option used in Phase 1 when METHØD data is missing and user-input modes are used directly (see Note 6).

m_1, m_2 - Optional output requests (see Note 4).

Notes: 1. All references to the grid points and components not defined in the "boundary set" will be reduced out of the new substructure. Any subsequent reference to these omitted degrees of freedom in CØMBINE, CREDUCE, MREDUCE, REDUCE, or SØLVE operations generates an error condition.

2. The resulting substructure will be defined in terms of the following degrees of freedom:

u_b - boundary grid point displacements.

δ_j - modal displacements relative to static deflection shapes induced by boundary inertia.

δ_o - Inertia relief generalized coordinates defined by inertia relief deflection shapes occurring from boundary point rigid body accelerations.

Note that a new substructure will be automatically created to define coordinates δ_o and δ_j. The name will be the same as given by NAME and the point identification numbers are 1-6 for δ_o and 101, 102,... for δ_j.

3. The same transformations applied to the stiffness matrix will be applied to the loads, mass, and damping matrices for the new substructure. See the NASTRAN Theoretical Manual for a discussion of this effect.

4. The following output requests are available for the MREDUCE operation (* marks recommended options):

Code	Output
1*	Current problem summary
2	Boundary set summary
3	Summary of grid point ID numbers in each boundary set
4	The EQSS item for the structure being reduced

(Continued)

Code	Output (continued)	
5*	The EQSS item	These requests write formatted SØF items for the new reduced pseudostructure
6*	The BGSS item	
7	The CSTM item	
8	The PLTS item	
9*	The LØDS item	
10*	Modal dof set summary	
11	Fixed set summary	
12	Summary of grid point ID numbers in each fixed set	

5. The options ØLDMØDES and ØLDBØUND allow the user to rerun the reduction and:

   a. Change the boundary without recalculating modes.

   b. Change the modes without the boundary condensation calculations.

   c. Select a different mode range from the existing vectors and avoid recalculating modes and boundary matrices.

6. The user must provide the actual mode data in Phase 1 when USERMØDES = N is given. Two options are provided:

   a. If N = 1, the structure must be entirely defined by a finite element model and the eigenvectors for the NASTRAN u_a set provided in data block PHIS input using DMI cards.

   b. If N = 2, the entire structure need not be defined. The user provides eigenvectors and forces of constraint only at the selected boundary points as well as eigenvalues and modal masses. Residual stiffness and mass matrices may also be provided to define properties at the boundary points. Use DMI and DTI cards for these data.

7. If the RSAVE card is included, the decomposition product of the interior point stiffness matrix (LMTX item) is saved on the SØF file. This matrix will be used in the data recovery for the omitted points. If it is not saved it will be regenerated when needed.

8. Exercising the ØLDMØDES option, the user must use the following sequence of commands:

   EDIT(32) new name (previous modal reduction name)

   EDIT(16) name

   MREDUCE name

   NAME = new name

(Continued)

9. Exercising the ØLDBØUND option, the user must use the following sequence of commands:

   EDIT(32) new name (previous modal reduction name)

   EDIT(768) name

   MREDUCE name

   NAME = new name

10. Exercising both the ØLDMØDES and ØLDBØUND options concurrently the user must use the following sequence of commands:

    EDIT(32) new name (previous modal reduction name)

    EDIT(512) name

    MREDUCE name

    NAME = new name

SUBSTRUCTURE CONTROL DECK

Substructure Mode Control <u>ØPTIØNS</u> - Defines Matrix Types

<u>Purpose</u>: This allows the user to selectively control the type of matrices being processed.

<u>Request Format</u>:

ØPTIØNS   m1,m2,m3

<u>Subcommands</u>: None

<u>Definition</u>:

m1,m2,m3 - Any combination of the characters K, M, B, K4, and either P or PA, where:

K = Stiffness Matrices
M = Mass Matrices
P = Load Matrices
PA = Appended Load Vectors
B = Viscous Damping Matrices
K4 = Structure Damping Matrices

<u>Notes</u>: 1. The default depends on the NASTRAN rigid format:

Rigid Format	Default
1 - Statics	K,P
2 - Inertia Relief	K,M,P
3 - Normal Modes	K,M
8 - Frequency Response	K,M,P,B,K4
9 - Transient Response	K,M,P,B,K4

2. In a Phase 1 execution, Rigid Formats 1 and 3 will provide only two of the matrices, as shown above. In Rigid Format 1, the mass matrix is not generated. In Rigid Format 3, the loads matrix is not generated. An error condition will result unless the user adds the required DMAP alters to provide the requested data.

3. Stiffness, mass, load, or damping matrices <u>must</u> exist if the corresponding K, M, P, PA, B, or K4 option is requested in the subsequent Phase 2 run.

4. Matrices or loads may be modified by rerunning the substructure sequence for only the desired type. However, the old data <u>must</u> be deleted first with the EDIT or DELETE command. See Section 1.10.2 for the actual item names.

5. The append load option, PA, is used when additional load sets are required for solution, and it is not desired to regenerate existing loads. To generate these new load vectors, re-execute all required Phase 1 runs with the new load sets and ØPTIØN = PA. Then, repeat the Phase 2 operations with ØPTIØN = PA. At each step, the new vectors are appended to the existing loads so that all load vectors will be available in the SØLVE stage.

6. Each ØPTIØN command overrides the preceding command to control subsequent steps of the substructure process.

7. When executing the SØLVE command, the option selected must provide the matrices required for the rigid format being executed.

Substructure Operating File Declaration PASSWØRD

Purpose: This declaration is required in the substructure command deck. The password is written on the SØF file and is used to protect the file and insure that the correct file is assigned for the current run.

Request Format:

PASSWØRD   password

Subcommands: None

Definition:

password - BCD password for the SØF (8 characters maximum). See the SØF file declaration card description.

SUBSTRUCTURE CONTROL DECK

Substructure Command PLØT - Substructure Plot Command

Purpose: This operation is used to plot the undeformed shape of a substructure which may be composed of several component substructures. This command initiates the execution of a plot at any stage of the substructure process. The actual plot commands; origin data, etc., must be included in the normal case control data.

Request Format:

PLØT name

Subcommands: None

Definitions:

name - Name of component substructure to be plotted.

Notes: 1. The set of elements to be plotted will consist of all the elements and grid points saved in Phase 1 for each basic substructure comprising the substructures named in the PLØT command. (Only one plot set from each basic substructure is saved in Phase 1.)

2. The structure plotter output request packet, while part of the standard Case Control Deck, are treated separately in Sections 4.2 and 4.3, respectively.

Substructure Command <u>RECØVER</u> - Phase 2 Solution Data Recovery

<u>Purpose</u>: This operation recovers displacements and boundary forces on specified substructures in the Phase 2 execution. The results are saved on the SØF file and they may be printed upon user request. This command should be input after the SØLVE command to store the solution results on the SØF file.

<u>Request Format</u>:

RECØVER s-name

<u>Subcommands</u>:

SAVE = name

PRINT = name

DISP $= \left\{\begin{array}{c}\text{ALL}\\ \text{n}\\ \underline{\text{NØNE}}\end{array}\right\}$

SPCF $= \left\{\begin{array}{c}\text{ALL}\\ \text{n}\\ \underline{\text{NØNE}}\end{array}\right\}$

ØLØAD $= \left\{\begin{array}{c}\text{ALL}\\ \text{n}\\ \underline{\text{NØNE}}\end{array}\right\}$

BASIC = b-name

ENERGY $= \left\{\begin{array}{c}\text{ALL}\\ \text{n}\\ \underline{\text{NØNE}}\end{array}\right\}$

for static analysis only:

SØRT $= \left\{\begin{array}{c}\underline{\text{SUBCASE}}\\ \text{SUBSTRUCTURE}\end{array}\right\}$

SUBCASES $= \left\{\begin{array}{c}\underline{\text{ALL}}\\ \text{n}\\ \text{NØNE}\end{array}\right\}$

for normal modes analysis only:

SØRT $= \left\{\begin{array}{c}\underline{\text{MØDES}}\\ \text{SUBSTRUCTURE}\end{array}\right\}$

MØDES $= \left\{\begin{array}{c}\underline{\text{ALL}}\\ \text{n}\\ \text{NØNE}\end{array}\right\}$

RANGE $= f_1, f_2$

(Continued)

for dynamic analysis only:

SØRT $= \left\{\begin{array}{l} \text{FREQ} \\ \text{TIME} \\ \text{SUBSTRUCTURE} \end{array}\right\}$

STEPS $= \left\{\begin{array}{l} \text{ALL} \\ n \\ \text{NØNE} \end{array}\right\}$

RANGE $= f_1, f_2$

UIMPRØVE

Definitions:

s-name	- Name of the substructure named in a prior SØLVE command from which the solution results are to be recovered.
name	- Name of the component structure for which results are to be recovered. May be the same as "s-name"
b-name	- Name of component basic substructure that following output requests are to apply to.
ALL	- Output for all points will be produced.
NØNE	- No output is to be produced.
n	- Set identification number of a SET card appearing in Case Control. Only output for those points, subcases, modes, frequencies, or time steps whose identification number appears on this SET card will be produced.
f_1, f_2	- Range of frequencies or times for which output will be produced. If only f_1 is present the range is assumed to be 0 - f_1.
SUBCASE	- All output requests for each subcase will appear together.
MØDES	- All output requests for each mode will appear together.
SUBSTRUCTURE	- All output requests for each basic substructure will appear together.
TIME	- All output requests for each time step will appear together (RF 9).
FREQ	- All output requests for each frequency will appear together (RF 8).

Output Requests: Printed output produced by the RECØVER PRINT command can be controlled by requests present in either Case Control or the RECØVER command in the Substructure Control Deck. If no output requests are present, the PRINT command is equivalent to SAVE and no output will be printed.

The RECØVER output options described above may appear after any PRINT command. These output requests will then override any Case Control requests. The output requests for any PRINT command can also be specified for any or all basic component substructures of the results being recovered. These requests will then override any requests in Case Control or after the PRINT command.

(Continued)

Example of output control:

```
RECØVER SØLSTRCT
   PRINT    ABSC
      SØRT = SUBSTRUCTURE  }
      DISP = ALL           }   basic defaults for ABDC output
      ØLØAD = 10           }
      BASIC    A           }
         DISP = 5          }   override requests for BASIC A
      BASIC    C           }
         ØLØAD = NØNE      }   override requests for BASIC C
         SUBCASES = 20     }
   SAVE   ABC
```

Notes:

1. SAVE will save the solution for substructure "name" on the SØF. PRINT will save and print the solution.

2. If the solution data already exists on the SØF, the existing data can be printed without costs of regeneration with the PRINT command.

3. For efficiency, the user should order multiple SAVE and/or PRINT commands so as to trace one branch at a time starting from his solution structure.

4. Reaction forces are computed for a substructure only if (1) the substructure is named on a PRINT subcommand and, (2) an output request for SPCFØRCE or modal energies exists in the Case Control or the RECØVER command.

5. All set definitions should appear in Case Control to ensure their availability to the RECØVER module.

6. The SØRT output option should only appear after a PRINT command. Any SØRT commands appearing after a BASIC command will be ignored.

7. If both a MØDES (or STEPS) request and a RANGE request appear for dynamic analysis, both requests must be satisfied for any output to be produced.

8. The media, print or punch, where output is produced is controlled through Case Control requests. If no Case Control requests are present, the default of print is used.

9. If the UIMPRØVE request is present for a substructure that was input to a REDUCE, MREDUCE, or CREDUCE, an improved displacement vector will be generated. This vector will contain the effects of inertia and damping forces.

10. The ENERGY request will cause the calculation of modal energies on all included and excluded modal dof for a modal reduced substructure. This request should appear for the substructure that was input to the modal reduce operation so that required data needed for the excluded mode calculations exists. This request requires that the UVEC item exists for the next highest level structure.

11. For dynamic analysis, the printed loads output will include dynamic loads only for the solution substructure in the same run that the solution was obtained. For any lower level substructures or on any run after the solution, only static loads will be printed.

12. The user can specify print thresholds for all printout. If the absolute value is less than the threshold, the value will be set to zero. The following thresholds can be input on PARAM bulk data cards.

    UTHRESH - displacement, velocity, and acceleration
    PTHRESH - load threshold
    QTHRESH - reaction force threshold

Substructure Command REDUCE - Phase 2 Reduction to Retained Degrees of Freedom

Purpose: This operation performs a Guyan matrix reduction process for a specified component substructure, otherwise known as matrix condensation. It produces the same result as obtained by the specification of NASTRAN ØMIT or ASET data. The purpose is to reduce the size of the matrices. In static analysis only points on the boundary need be retained. In dynamics, the boundary points and selected interior points are retained.

Request Format:

REDUCE name

Subcommands:

NAME - new name

BØUNDARY - n

ØUTPUT - m_1, m_2,...

RSAVE

Definitions:

name - Name of substructure to be reduced.

new name - Name of resulting substructure.

n - Set identification number of BDYC bulk data cards which define sets of retained degrees of freedom for the resulting reduced substructure matrices.

m_1, m_2, etc. - Optional output requests (see Note 3).

Notes: 1. All references to the grid points and components not defined in the "boundary set" will be reduced out of the new substructure. Any subsequent reference to these omitted degrees of freedom in CØMBINE, REDUCE, or SØLVE operations generates an error condition.

2. The same transformations will be applied to the reduced mass matrix for the new substructure. See the NASTRAN Theoretical Manual for a discussion of this effect.

3. The following output requests are available for the REDUCE operation (* marks recommended output options):

CODE	OUTPUT	
1*	Current problem summary	
2	Boundary set summary	
3	Summary of grid point ID numbers in each boundary set	
4	The EQSS item for the structure being reduced	
5*	The EQSS item	These requests write formatted SØF items for the new reduced pseudostructure
6*	The BGSS item	
7	The CSTM item	
8	The PLTS item	
9*	The LØDS item	

4. If the RSAVE card is included, the decomposition product of the interior point stiffness matrix (LMTX item) is saved on the SØF file. This matrix will be used in the data recovery for the omitted points. If it is not saved, it will be regenerated when needed.

Substructure Command RESTØRE

Purpose: To reload the SØF from an external file created with the DUMP command.

Request Format:

RESTØRE filename $\left\{ \begin{matrix} \text{,DISK} \\ \text{,}\underline{\text{TAPE}} \end{matrix} \right\}$

Subcommands: None

Definitions:

Filename - Name of the external file. Any one of the following: INPT, INP1,..., INP9.

DISK - File resides on a direct access device.

TAPE - File resides on tape.

Notes:
1. The external file must have been created with the DUMP command.
2. The SØF must be declared as 'NEW' on the SØF command.
3. RESTØRE must be the very first substructure command following the SØF and PASSWØRD declarations.
4. The SØF size declarations for the RESTØRE command must be exactly the same as for the SØF which was DUMPed. The DUMP/RESTØRE commands can not be used to increase the size of the SØF.

Substructure Mode Control RUN - Specifies Run Options

Purpose: This command is used to limit the substructure execution for the purpose of checking the validity of the input data. It allows for the processing of input data separately from the actual execution of the matrix operations.

Request Format:

$$\text{RUN} \quad \left\{ \begin{array}{l} \text{DRY} \\ \text{GØ} \\ \text{DRYGØ} \\ \underline{\text{STEP}} \end{array} \right\}$$

Subcommands: None

Definitions:

DRY - Limits the execution to table and transformation matrix generation. Matrix operations are skipped.

GØ - Limits the execution to matrix generation only. This mode must have been preceded by a successful RUN=DRY or RUN = STEP execution.

DRYGØ - Will cause execution of a complete dry run for the entire job, followed by a RUN=GØ execution if no fatal errors were detected.

STEP - Will cause the execution of both DRY and GØ operations one step at a time.

Notes:

1. The DRY, GØ, and STEP options may be changed at any step in the input substructure command sequence. If the DRYGØ option is used, the RUN card must appear only once at the beginning.

2. If a fatal error occurs during the first pass of the DRYGØ option, the program exits at the completion of all DRY operations.

3. The RUN = DRY option is handled differently for MREDUCE and CREDUCE because the matrix operations must be performed in order to generate the table and transformation matrix data. Input data only will be checked and no subsequent commands will be executed.

4. The RUN = GØ and ØPTIØNS = K combination is illegal for any of the reduce operations, REDUCE, MREDUCE, or CREDUCE.

Substructure Operation File Declaration SØF - Assigns Physical Files for Storage of the SØF

Purpose: This declaration defines the names and sizes of the physical NASTRAN files the user assigns for storage of the SØF file. At least one of these declarations must be present in each substructure command deck. As many SØF declarations are required in the substructure command deck on each run as there are physical files assigned for the storage of the SØF file.

Request Format:

SØF(no.) = filename, filesize, $\left\{ \begin{matrix} \text{ØLD} \\ \text{NEW} \end{matrix} \right\}$

Subcommands:

PASSWØRD = password

Definitions:

no. - Integer index of SØF file (1, 2, etc.) in ascending order of files required for storage of the SØF. The maximum index is 10.

filename - User name for an SØF physical file.

filesize - Size of allocated file space in kilowords, default = 100.

ØLD - SØF data is assumed to already exist on the file.

NEW - The SØF is new. In this case, the SØF will be initialized.

password - BCD password for the SØF (8 characters maximum) used to protect the file and insure that the correct file is assigned for the current run (see the PASSWØRD card description).

Notes:

1. If more space is required for storage of the SØF file, additional physical files may be declared. Alternately, the file size parameter on a previously declared file may be increased, but only on the last physical file if more than one is used (on IBM the size of an existing file may not be increased.

2. Once an SØF declaration is made, the index of the SØF file must always be associated with the same file name. File names may not be changed from run to run.

3. The file names of each physical SØF file must be unique.

4. The declared size of the SØF may be reduced by the amount of contiguous free-space at the end of the logical SØF file. This may be accomplished by removing the physical file declaration for those unused files which have the highest sequence numbers. An attempt to eliminate a portion of the SØF which contains valid data will result in a fatal error.

5. If the NEW parameter is present on any one of the SØF declarations, the entire logical SØF is considered new. Therefore, if an additional physical file is added to an existing SØF, the NEW parameter should not be included on any declarations.

6. The following conventions should be used for the file name declarations on each of the four NASTRAN computers:

CDC/CYBER

Must be a 4-character alphanumeric name with no special characters or blanks allowed. The file name used on the SØF declaration must correspond to ones used on the system REQUEST or ATTACH card. Note that after a NASTRAN execution, the SØF files should be catalogued or extended.

(Continued)

Examples:

1. Create a new SØF file with a filename of SØF1 and catalogue it.

```
REQUEST(SØF1,*PF)
NASTRAN.
CATALØG(SØF1,username)
789
:
:
NASTRAN data cards including the SØF declaration --
SØF(1)=SØF1,1000,NEW
:
:
6789
```

2. Use of an existing SØF file with a filename of ABCD.

```
ATTACH(ABCD,username)
NASTRAN.
EXTEND(ABCD)
789
:
:
NASTRAN data cards including the SØF declaration --
SØF(1)=ABCD,1000
:
:
6789
```

UNIVAC 1108/1110

The filename used on the SØF declaration must specify one of the NASTRAN user files INPT, INP1,..., INP9.

Examples:

1. Create a new SØF file named INPT.

```
@ASG,U INPT.,F///1000
@HDG,N
@XQT *NASTRAN.LINK1
.
NASTRAN FILES=INPT
.
NASTRAN data cards including the SØF declaration --
SØF(1)=INPT,400,NEW
:
:
@FIN
```

2. Use of an existing SØF file with a filename of INP7.

```
@ASG,AX INP7.
@HDG,N
@XQT  *NASTRAN.LINK1
.
NASTRAN FILES=INP7
.
NASTRAN data cards including the SØF declaration --
SØF(1)=INP7,250
:
:
@FIN
```

(Continued)

IBM 360/370

The file name used on the SØF declaration must specify a FØRTRAN unit by using the form FTxx from the table of allowable file names shown below which correspond to the direct access devices that are supported under the SØF implementation. The allocation of space for the direct access FØRTRAN data sets can be made in terms of blocks, tracks or cylinder. If the allocation is in blocks, the block size in the space allocation corresponds to (BUFFSIZE-4)*4 bytes where BUFFSIZE is the GINØ buffer size found in SYSTEM(1).

In order to use the SØF on IBM computers, it is necessary to specify the PARM on the EXEC PGM=NASTRAN card. This PARM sets the amount of core (in bytes) NASTRAN releases to the operating system for system use and FØRTRAN buffers. The following formula should be used to determine the value for the PARM:

PARM = (4096 + m*((BUFFSIZE-4) + 64))*4 single buffering, BUFNØ=1
(4096 + m*(2*(BUFFSIZE-4) + 96))*4 double buffering, BUFNØ=2

where m = number of physical datasets comprising the SØF.

Examples:

1. Create a new SØF data set with a filename of FT11.

```
//NSGØ EXEC NASTRAN,PARM.NS='CØRE=(,60K)'
//NS.FT11F001 DD DSN = User Name, UNIT=2314, VØL=SER=User No.,
//   DISP=(NEW,KEEP), SPACE=TRK,(1000)), DCB=BUFNØ=1
//NS.SYSIN DD *
NASTRAN BUFFSIZE=1826
.
.
.
NASTRAN data cards including the SØF delcaration --

SØF(1)=FT11,,NEW
.
.
.
/*
```

Notes:

1. The SØF parameters - filename, filesize, and (ØLD/NEW) are positional parameters. The filesize parameter is not required for IBM 360/370 computers, but its position must be noted if NEW is coded for the SØF file.

2. The dataset disposition must be DISP=(NEW,KEEP) when the SØF dataset is created. However, an existing SØF dataset may be re-initialized by coding NEW on the SØF declaration in the NASTRAN data deck. In this case, the disposition on the DD card must be coded DISP=ØLD.

2. Use of an existing SØF dataset with a filename of FT23.

```
//NS EXEC NASTRAN,PARM.NS='CORE=(,72K)'
//NS.FT23F001 DD DSN = User Name, UNIT=3330, VØL=SER=User No.,
// DCB=BUFNØ=1, DISP=ØLD
//NS.SYSIN DD *
NASTRAN BUFFSIZE=3260
SØF (1)=FT23
.
.
.
/*
```

(Continued)

SØF (Cont.)

SØF File Name	FØRTRAN Unit DDName	SØF File Name	FØRTRAN Unit DDName
FT02	FT02F001	FT16	FT16F001
FT03	FT03F001	FT17	FT17F001
FT08	FT08F001	FT18	FT18F001
FT09	FT09F001	FT19	FT19F001
FT10	FT10F001	FT20	FT20F001
FT11	FT11F001	FT21	FT21F001
FT12	FT12F001	FT22	FT22F001
FT15	FT15F001	FT23	FT23F001

Note: A maximum of 10 SØF file names is allowed in any NASTRAN substructuring run.

DEC VAX

The filename used on the SØF declaration must be of the form FTxx thereby implying the use of the FØRTRAN logical unit FØROxx for the SØF. Any of the FØRTRAN logical units FØR014 through FØR023 may be used for the SØF, provided they are not otherwise assigned.

Examples:

1. Create a new SØF with the file name TEST.SØF

```
$ CREATE TEST1.CØM
      $ASSIGN TEST.SØF FØR022
      $@NASTRAN TEST1.DT
      $EXIT

$ SUBMIT/QUEUE=NASTRAN TEST1.CØM
```

The file NASTRAN.CØM contains the command procedure for executing NASTRAN and the file TEST1.DT contains the NASTRAN data including the SØF declaration -- SØF(1) = FT22,1000,NEW

2. Use an existing SØF with the file name TEST.SØF

```
$ CREATE TEST2.CØM
      $ASSIGN TEST.SØF FØR022
      $@NASTRAN TEST2.DT
      $EXIT

$ SUBMIT/QUEUE=NASTRAN TEST2.CØM
```

The file NASTRAN.CØM contains the command procedure for executing NASTRAN and the file TEST2.DT contains the NASTRAN data including the SØF declaration -- SØF(1) = FT22,1000

Substructure Command SØFIN

Purpose: To copy substructure items from an external file to the SØF.

Request Format:

$$\text{SØFIN} \left(\begin{Bmatrix} \text{EXTERNAL} \\ \underline{\text{INTERNAL}} \end{Bmatrix} \right) \quad \text{filename} \quad \begin{Bmatrix} \text{,DISK} \\ \underline{\text{TAPE}} \end{Bmatrix}$$

Subcommands:

$$\text{POSITION} = \begin{Bmatrix} \text{REWIND} \\ \underline{\text{NØREWIND}} \end{Bmatrix}$$

$$\text{NAMES} = \begin{Bmatrix} \text{substructure name} \\ \underline{\text{WHØLESØF}} \end{Bmatrix}$$

$$\text{ITEMS} = \begin{Bmatrix} \underline{\text{ALL}} \\ \text{MATRICES} \\ \text{PHASE3} \\ \text{TABLES} \\ \text{item name} \end{Bmatrix}$$

Definitions:

EXTERNAL - File was written on a different computer type.

INTERNAL - File was written with GINØ on the same computer type.

Filename - Name of the external file. If the file is in INTERNAL format, filename must specify INPT, INP1,...,INP9. If the file is in EXTERNAL format, filename must specify a FØRTRAN unit by using the form FØRT1, FØRT2,...,FØRT32.

DISK - File is located on a direct access device.

TAPE - File is located on a tape.

PØSITION - Specifies initial file position.

REWIND: file is rewound
NØREWIND: input begins at the current position

NAMES - Identifies a substructure for which data will be read. If NAMES=WHØLESØF is coded, and no other NAMES subcommands appear for the current SØFIN command, all substructure items found on the external file from the point specified by the PØSITIØN subcommand to the end-of-file are copied to the SØF.

ITEMS - Identifies the data items which are to be copied to the SØF for each substructure specified by the NAMES subcommands.

ALL: all items
MATRICES: all matrix items
PHASE3: the UVEC, QVEC, and SØLN items
TABLES: all table items
item name: name of an individual item

Notes: 1. Filename is required. The other SØFIN operands are optional.

2. All subcommands are optional.

(Continued)

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3. The NAMES subcommand may appear up to five times for each SØFIN command.

4. If a substructure name of an item which is to be copied to the SØF does not exist on the SØF, it is added to the SØF. MDI pointers for higher level, combined substructures and lower level substructures are restored.

5. For the EXTERNAL form of this command all the items on the file are read in and added to the SØF. The PØSITIØN subcommand should be specified as REWIND and user specifications for all other subcommands are ignored.

6. SØFØUT is the companion substructure command.

7. When an internal-formated file is located on tape and extends over multiple reels, care should be taken when using the SØFIN command. The commands should be ordered so that all the desired data is retrieved on a single pass through the tape. The following suggestions are helpful:

   a. Order the SØFIN command to obtain data in the order they exist on the tape. If this order is not known, the CHECK command will list the contents of the tape.

   b. The first SØFIN command should specify PØSITIØN=REWIND and all subsequent commands should use PØSITIØN=NØREWIND.

   c. The individual items should be requested by name. The ALL, MATRICES, TABLES or PHASE3 specification should not be used for the ITEMS subcommand unless all the appropriate items are on the tape. If some are not present, the tape will be searched to the end of the last reel and subsequent commands will not be executable because they will attempt to rewind back to the first tape.

8. On IBM computers and for the EXTERNAL form of this command, the following DD card should be used:

```
//NS.FTxxF001 DD DSN=username,UNIT=2400-1,DISP=(,KEEP),
//     LABEL=(,NL),DCB=(RECFM=FB,LRECL=132,BLKSIZE=3960,
//     TRTCH=T,DEN=2)
```

9. Only one item may appear as an ITEMS subcommand per NAMES subcommand. Selective items may be referenced by repeating the NAMES subcommand.

Substructure Command SØFØUT

Purpose: To copy substructure items from the SØF to an external file.

Request Format:

SØFØUT ({EXTERNAL / INTERNAL}) filename {,DISK / TAPE}

Subcommands:

PØSITIØN = {REWIND / NØREWIND / EØF}

NAMES = {substructure name / WHØLESØF}

ITEMS = {ALL / MATRICES / PHASE3 / TABLES / item name}

Definitions:

EXTERNAL - File will be written so that it may be read on a different computer type.

INTERNAL - File will be written with GINØ.

Filename - Name of the external file. If the file is in INTERNAL format, filename must specify INPT, INP1,...,INP9. If the file is in EXTERNAL format, filename must specify a FØRTRAN unit by using the form FØRT1, FØRT2,...,FØRT32.

DISK - File is located on a direct access device.

TAPE - File is located on a tape.

PØSITIØN - Specifies initial file position. (See Note 6)

REWIND: file is rewound
NØREWIND: output begins at the current position
EØF: file is positioned to the point immediately preceding the end-of-file mark.

NAMES - Identifies a substructure for which data will be written. If NAMES=WHØLESØF is coded and no other NAMES subcommands appear for the current SØFØUT command, all substructure items found on the SØF are copied to the external file.

ITEMS - Identifies the data items which are to be copied to the external file for each substructure specified by the NAMES subcommands.

ALL: all items
MATRICES: all matrix items
PHASE3: the UVEC, QVEC, and SØLN items
TABLES: all table items
item names: name of an individual item

Notes: 1. Filename is required. The other SØFØUT operands are optional.

(Continued)

2. All subcommands are optional.

3. The NAMES subcommand may appear up to five times for each SØFØUT command.

4. PLTS items of pseudostructures reference the PLTS items of the component basic substructures. Therefore, in order to save all data necessary to plot a pseudostructure, the PLTS items of its component basic substructures must be saved as well as the PLTS item of the pseudostructure.

5. For the external form of this command, PØSITIØN=NØREWIND has the effect of positioning the file to the end-of-file.

6. PØSITIØN=REWIND should be coded for the first write to a new file.

7. SØFIN is the companion substructure command.

8. On IBM computers and for the EXTERNAL form of this command, the following DD card should be used:

```
//NS.FTxxF001 DD DSN=username,UNIT=2400-1,DISP=(,KEEP),
//     LABEL=(,NL),DCB=(RECFM=FB,LRECL=132,BLKSIZE=3960,
//     TRTCH=T,DEN=2)
```

9. Only one item may appear as an ITEMS subcommand per NAMES subcommand. Selective items may be referenced by repeating the NAMES subcommand.

Substructure Command SØFPRINT - Requests SØF File Verification

Purpose: To print selected contents of the SØF file for data checking purposes.

Request Format:

SØFPRINT(opt)   name, item1, item2, etc.

Subcommands: None

Definitions:

opt - Integer, control option, default = 0.

opt = 1: prints data items only
opt = 0: prints table of contents
opt = -1: prints both

name - Name of substructure for which data is to be printed.

item1, item2 - SØF item name, used only when opt ≠ 0, limit = 5 (see Table 2, Section 1.10.2).

Notes: 1. If only the table of contents is desired (opt = 0) this command may be coded:

SØFPRINT TØC

On the page heading for the table of contents, the labels are defined as follows:

SS - Secondary substructure number (successor)
PS - Primary substructure number (predecessor)
LL - Lower level substructure number
CS - Combined substructure number
HL - Higher level substructure number
TYPE - Substructure type

B - basic substructure
C - combined substructure
R - Guyan reduced substructure
M - real modal reduced substructure
CM - complex modal reduced substructure

Any of the above types will have a prefix "I" if it is an image substructure resulting from an EQUIV operation.

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Substructure Command SØLVE - Substructure Solution

Purpose: This command initiates the substructure solution phase. The tables and matrices for the pseudostructure are converted to their equivalent NASTRAN data blocks. The substructure grid points referenced on bulk data cards SPCS, MPCS, etc., are converted to pseudostructure scalar point identification numbers. The NASTRAN execution then proceeds as though a normal structure were being processed.

Request Format:

SØLVE name

Subcommands: None (Case Control and bulk data decks control the operations.)

Definition:

name - Name of pseudostructure to be analyzed with NASTRAN.

Notes:

1. The allowable NASTRAN Rigid Formats are 1, 2, 3, 8, and 9.
2. Before requesting a SØLVE, the user should check to be sure that all necessary matrices are available on the SØF file. For instance, loads and stiffness matrices are necessary in statics analysis. Mass and stiffness matrices are necessary in eigenvalue analysis, etc.
3. If the ØPTIØNS command has been used, an additional ØPTIØNS command may be necessary to ensure that the matrices required are available for the SØLVE operation.
4. Static load combinations of the original Phase 1 load vectors may be defined by the bulk data card LØADC. Loads of this type may be used in Rigid Format 9 (Direct Transient Analysis) in lieu of DAREA dynamic load data.
5. The SØLVE name command should always be followed by RECØVER name to assure the solution data are saved on the SØF.
6. The SØLVE command may only be used in Phase 2 executions.

SUBSTRUCTURE CONTROL DECK

Substructure Command SUBSTRUCTURE - Initiates the Substructure Control Data Deck

Purpose: This command initiates the processing for automated substructuring and defines the phase of the analysis. It must be the first card in the Substructure Control Deck.

Request Format:

$$\text{SUBSTRUCTURE} \begin{Bmatrix} \text{PHASE1} \\ \text{PHASE2} \\ \text{PHASE3} \end{Bmatrix}$$

Subcommands:

NAME = name (required and valid only in PHASE1)

SAVEPLØT = n (used only in PHASE1)

Definitions:

name - The name assigned to the basic substructure which is being created in PHASE1.

n - The plot set identification used to define the set of elements and grid points to be saved in PHASE1 for subsequent plotting in PHASE2. Only one set may be defined for any basic substructure.

Notes:

1. The mode command RUN=STEP is assumed initially if the explicit command is not given immediately following the SUBSTRUCTURE command.
2. No further substructure commands are required for PHASE1.
3. Additional substructure commands are required for PHASE2.
4. For PHASE3 operations, RECØVER and BRECØVER are equivalent commands and one of them must be present.
5. Imbedded blanks within the individual elements of this card are not allowed. An unrecognizable command causes the program to automatically assume a PHASE2 solution.

3. RIGID FORMATS

3.1 GENERAL DESCRIPTION OF RIGID FORMATS

The most general way of using NASTRAN is with a user written Direct Matrix Abstraction Program (DMAP). This procedure permits the user to execute a series of matrix operations of his choice along with any utility modules or executive operations that he may need. The user may even choose to write a module of his own. The rules governing all of these operations are described in Section 5.

In order to relieve the user of the necessity of constructing a DMAP sequence for each of his problems, a number of such sequences have been included in NASTRAN as rigid formats. A rigid format consists of two parts. The first part is a DMAP sequence that is stored in NASTRAN and available to the user by specifying the number of the rigid format on the SØL card in the Executive Control Deck. The second part of a rigid format is a set of restart tables that automatically modify the series of DMAP operations to account for any changes that are made in any part of the Data Deck when making a restart, after having previously run all, or a part, of the problem. Without such tables, the user would have to carefully modify his DMAP sequence to account for the conditions surrounding each restart. The chances for error in making these modifications for restart are very great. The restart tables not only relieve the user of the burden of modifying his DMAP sequence, but also assure him of a correct and efficient program execution.

In addition to the DMAP sequence provided with each rigid format, a number of options are available, which are subsets of each complete DMAP sequence. Subsets are selected by specifying the subset numbers (zero for the complete DMAP sequence) along with the rigid format number on the SØL card in the Executive Control Deck. See the description of the SØL card in Section 2.2.1 for the list of available subsets.

If the user wishes to modify the DMAP sequence of a rigid format in some manner not provided for in the available subsets, he can use the ALTER feature described in Section 2. Typical uses are to schedule an EXIT prior to completion, in order to check intermediate output, schedule the printing of a table or a matrix for diagnostic purposes, and to delete or add a functional module to the DMAP sequence. (The manner in which DMAP ALTERs are handled in restarts is discussed in Section 3.1.5.) The user should be familiar with the rules for DMAP programming, as described in Section 5, prior to making ALTERs to a rigid format.

The following rigid formats for structural analysis are currently included in NASTRAN:

1. Static Analysis

2. Static Analysis with Inertia Relief
3. Normal Mode Analysis
4. Static Analysis with Differential Stiffness
5. Buckling Analysis
6. Piecewise Linear Static Analysis
7. Direct Complex Eigenvalue Analysis
8. Direct Frequency and Random Response
9. Direct Transient Response
10. Modal Complex Eigenvalue Analysis
11. Modal Frequency and Random Response
12. Modal Transient Response
13. Normal Modes Analysis with Differential Stiffness
14. Static Analysis with Cyclic Symmetry
15. Normal Modes Analysis with Cyclic Symmetry

The following rigid formats for heat transfer analysis are included in NASTRAN:

1. Linear Static Heat Transfer Analysis
3. Nonlinear Static Heat Transfer Analysis
9. Transient Heat Transfer Analysis

The following rigid formats for aeroelastic analysis are included in NASTRAN:

10. Modal Flutter Analysis
11. Modal Aeroelastic Response

3.1.1 Input File Processor

The Input File Processor operates in the Preface prior to the execution of the DMAP operations in the rigid format. A complete description of the operations in the Preface is given in the Programmer's Manual. The main interest here is to indicate the source of data blocks that are created in the Preface and hence appear only as inputs in the DMAP sequences of the rigid formats. None of the data blocks created by the Input File Processor are checkpointed, as they are always regenerated on restart. The Input File Processor is divided into five parts. The first part (IFP1) processes the Case Control Deck, the second part (IFP) processes the Bulk Data Deck, the third part (IFP3) performs additional processing of the bulk data cards associated with the conical shell element, and the fourth part (IFP4) performs additional processing of the bulk data

cards associated with the fluid element. The fifth section (IFP5) processes data related to acoustic cavity analysis.

IFP1 processes the Case Control Deck and creates the Case Control Data Block (CASECC), the Plot Control Data Block (PCDB), and the XY-Plot Control Data Block (XYCDB). IFP1 also examines all of the cards, except those associated with plotting, for errors in format or use. If errors are detected, they are classed as either fatal or warning, and suitable error messages are provided. Reference to Section 2.3 will assist the user in correcting errors in the Case Control Deck. If the error is fatal, the Executive System will not allow the execution to continue beyond the completion of the Preface.

The Bulk Data Deck is sorted in the Preface, if necessary, before the execution of the second part of the Input File Processor. IFP checks all of the bulk data cards for errors according to the rules given for each card in Section 2.4. If errors are detected, suitable messages are provided to the user. If the error is classed as fatal, the Executive System will not allow the execution to continue beyond the completion of the Preface. IFP creates the data blocks that are input to the various part of the Geometry Processor (GEØM1, GEØM2, GEØM3 and GEØM4), the Element Properties Table (EPT), the Material Properties Table (MPT), the Element Deformation Table (EDT), and the Direct Input Table (DIT).

The third part of the Input File Processor (IFP3) converts the information on the special conical shell cards (CCØNEAX, CTRAPAX, CTRIAAX, FØRCEAX, MØMAX, MPCAX, ØMITAX, PCØNEAX, PØINTAX, PRESAX, PTRAPAX, PTRIAAX, RINGAX, SECTAX, SPCAX, SUPAX, and TEMPAX) to reflect the number of harmonics specified by the user on the AXIC card. This converted information is added to any existing information on data blocks GEØM1, GEØM2, GEØM3 and GEØM4.

The fourth part of the input file processor (IFP4) converts the information on the fluid-related cards (AXIF, BDYLIST, CFLUID2, CFLUID3, CFLUID4, DMIAX, FLSYM, FREEPT, FSLIST, GRIDB, PRESPT, and RINGFL) to reflect the desired harmonics, boundaries, and matrix input. This converted information is added to GEØM1, GEØM2, GEØM4 and MATPØØL.

The fifth part of the input file processor (IFP5) converts the information on the acoustic cavity related cards (AXSLØT, CAXIF2, CAXIF3, CAXIF4, CSLØT3, CSLØT4, GRIDF, GRIDS, and SLBDY) to equivalent structural scalar points, elements, scalar springs and plotting elements. This converted information is added to the GEØM1 and GEØM2 data blocks.

3.1.2 Functional Modules and Supporting DMAP Operations

The DMAP listings of the rigid formats currently included in NASTRAN are presented in the following sections. Following each listing is a subsection giving a brief description of all important DMAP operations in the rigid format. The DMAP statement numbers of the modules described therein are circled in the rigid format listings for ease of reference. Descriptions of all major functional modules are given in the Programmer's Module. Additional information is also given in the Theoretical Manual. Descriptions of all other NASTRAN modules are given in Section 5.

The executive modules in the following list appear repeatedly in the rigid formats. Since the purpose of these operations in a rigid format is obvious, they are omitted from the descriptions of the DMAP operations in the following sections. More complete descriptions of the executive modules are given in Section 5.

1. BEGIN indicates the beginning of the DMAP sequence constituting the rigid format.

2. FILE makes declarations relative to a particular file.

   ABC = TAPE states that file ABC will be assigned to a physical tape if one is available.

   DEF = APPEND states that file DEF may be extended as the result of an internal loop in the rigid format.

   GHI = SAVE states that file GHI should not be dropped after use as it may be needed for subsequent executions of an internal loop.

3. PRECHK actuates the automatic generation of explicit CHKPNT instructions. (PRECHK ALL automatically CHKPNTs all output data blocks from each functional module or PURGE instruction and all secondary data blocks of each EQUIV instruction.)* The CHKPNT instruction specifies a list of files to be written on the new problem tape (NPTP), including files that may have been purged, either because they were not generated in this particular execution or were explicitly purged with a PURGE instruction.

4. LABEL specifies a labeled point in the sequence of DMAP instructions. Labels are referenced by REPT, JUMP and CØND instructions.

5. PURGE specifies the names of files that are conditionally dropped based on the parameter named.

6. END indicates the end of the DMAP sequence constituting the rigid format and causes a normal termination when executed.

3.1.3 Checkpoint/Restart Procedures

The checkpoint/restart feature available in NASTRAN is a very sophisticated and useful capability. The purpose of this feature is to enable a user to checkpoint a NASTRAN run and then

* The only exceptions to this are the CASESS, CASEI and CASECC data blocks appearing as output in substructure analyses.

restart it (with or without changes in data) by executing only those modules that need to be executed for the restart.

There are several situations in which the use of the checkpoint/restart feature may be desirable. Some of these are listed below:

1. The user may wish to perform his analysis task in two or more stages by specifying scheduled exits in one or more runs.

2. The user may want to ensure that unscheduled exits (resulting from such causes as data errors, insufficient time, insufficient core or hardware failures) will not require him to repeat his entire analysis.

3. The user may wish to rerun his problem by making limited changes in his data.

Scheduled exits can be requested at any point in a rigid format by means of the ALTER feature. (The manner in which ALTERs are handled in restarts is discussed in Section 3.1.5). An exit is scheduled by inserting the following cards in the Executive Control Deck:

```
ALTER      K1  $
EXIT       K2  $
ENDALTER       $
```

where K1 = DMAP statement number after which exit will take place

and K2 = Number of times EXIT instruction will be skipped before being executed - default is zero. For use with loops, where the user wishes to execute the loop K2 times before scheduling the exit.

If the user chooses to restart the problem without making any changes, the Executive System will execute an unmodified restart following the last completed checkpoint.

Unscheduled exits are usually caused by errors on input cards or errors in the structural model resulting from missing or inconsistent input data. When such errors are detected, an unscheduled exit is performed accompanied with the output of the applicable user error messages. Following the correction of the input data errors, a modified restart can be performed.

Unscheduled exits may also occur because of machine failure or insufficient time allowance. In these cases, an unmodified restart is usually made following the last completed checkpoint. In some cases, where a portion of the problem has been completed, including the output for the completed portion, a modified restart must be made following an unscheduled exit due to insufficient time allowance. These situations are discussed under Case Control Deck requirements in the sections dealing with the individual rigid formats.

The initial execution of any problem must be made with a complete NASTRAN Data Deck, including all of the bulk data. However, all or part of the bulk data may be assembled from alternate input sources, such as the User's Master File or a module written by the user to generate

input. The User's Master File is described in Section 2.5 and user generated input is discussed in Section 2.6.

For restarts, the Bulk Data Deck consists only of delete cards (see Section 2.4) and new cards which the user wishes to add. The previous Bulk Data Deck is read from the Old Problem Tape. All other parts of the NASTRAN Data Deck, including the Executive Control Deck, the Case Control Deck, the BEGIN BULK card and the ENDDATA card must be resubmitted even though no changes are made in the control decks and no new bulk data is added. In addition, the RESTART cards (or dictionary) punched during the previous execution must be included in the Executive Control Deck. When changing rigid formats, the solution number (SØL) must be changed to the number of the new rigid format.

A New Problem Tape (NPTP) is constructed only when checkpointing is requested (CHKPNT YES) in the Executive Control Deck. The NPTP should be assigned to a physical tape or other storage device that can be dismounted and saved at the conclusion of the execution. At the completion of an initial execution, the NPTP contains the input deck, with the bulk data in sorted form, and all of the files that were checkpointed during the execution.

For restarts, the Old Problem Tape (ØPTP) is defined as the Problem Tape that was written during the previous execution. The NPTP is defined as the Problem Tape written during the current execution, beginning with the restart. At the completion of an unmodified restart, the NPTP contains the input deck, with the bulk data in sorted form, all files from the ØPTP that are necessary to complete the solution, and all of the files checkpointed during the current execution. At the completion of a modified restart, the NPTP is similar, except that the input deck is modified according to the information submitted for the restart.

3.1.4 Types of Restarts

The type of a restart is determined automatically by the program by comparing the input data of the restart run with that of the checkpoint run. The user need not be concerned about the manner in which this is done, but may be interested in knowing the resulting type.

The types of restarts presently recognized in NASTRAN are summarized in the following table.

Types of Restarts in NASTRAN

Restart data compared to checkpoint data	Resulting type of restart	Applicable environment	
		Rigid format	DMAP
No effective changes	Unmodified restart	Yes	Yes
Effective changes only to the Case Control Deck and/or the Bulk Data Deck	Modified restart	Yes	Yes
Change in rigid format	Modified restart with rigid format switch	Yes	No

In earlier versions of NASTRAN, an additional type of restart, called the pseudo modified restart, was recognized for cases involving changes only in output requests. This is no longer done since it is now handled as a special case of the modified restart.

The manner in which a restart is handled by the program depends on its type and on its environment (rigid format or DMAP environment). This is discussed in the following sections.

An important term that is frequently encountered in the following discussion is the reentry point for a restart. This is defined as the last reentry point specified in the restart dictionary. It is an integer equal to the instruction number of the DMAP instruction in the checkpoint run at which an unmodified restart will resume execution. (See Section 2.2.)

3.1.4.1 Unmodified Restart

An unmodified restart involves no effective changes to the data. The execution in this type of restart resumes at the reentry point. Unmodified restarts in both rigid format and DMAP environments are handled in an identical manner.

It is useful to distinguish between two types of unmodified restarts. These are described below.

- Unmodified restart in which the reentry point is not within a DMAP loop

This is the simplest type of restart possible. In this case, the execution flags for all DMAP instructions prior to the reentry point are turned off and the execution flags for all DMAP instructions from the reentry point onwards are turned on. All input files or data blocks required for the restart already exist on the ØPTP and will be retrieved.

- Unmodified restart in which the reentry point is within a DMAP loop.

In this case, initially, the execution flags for all DMAP instructions prior to the reentry point are turned off and the execution flags for all DMAP instructions from the reentry point onwards are turned on. This is so indicated in the DMAP source listing. However, subsequently, the DMAP instructions prior to the reentry point and within the DMAP loop are recognized and their execution flags are turned on. The user is informed about this in the output. Note, however, that the execution does resume at the reentry point, even though DMAP instructions prior to this point are turned on. DMAP instructions within the DMAP loop and prior to the reentry point are executed only if additional passes in the loop need to be executed. If the restart is within the last pass of the DMAP loop, obviously DMAP instructions within the loop and prior to the reentry point are not executed even though their execution flags are on.

All input files or data blocks required by the restart already exist on the ØPTP and will be retrieved.

3.1.4.2 Modified Restart

This type of restart involves one or more effective changes to the data in the Case Control Deck and/or in the Bulk Data Deck.

The heart of the restart logic for modified restarts in the rigid format environment is the Module Execution Decision Table (MEDT) associated with each rigid format. The MEDT for each rigid format actually comprises three distinct tables. These are the Card Name Restart Table, the Rigid Format Change Restart Table and the File Name Restart Table associated with that rigid format. (See Sections 1.10 and 7 of the Programmer's Manual.)

In the case of modified restarts in the rigid format environment, all DMAP instructions from the reentry points onwards have their execution flags turned on. In addition, this type of restart generally requires that certain DMAP instructions prior to the reentry point also be turned on, depending on the specific data changes involved. The DMAP instructions that need to be so turned on are determined from the Card Name Restart Table. The DMAP source listing provided in the output

indicates all the DMAP instructions whose execution flags are initially turned on by the above procedure.

Once the DMAP instructions are initially turned on as described above, the program checks to see if all of the required input data blocks are either being generated by prior modules or are available on the ØPTP for retrieval. If so, no additional DMAP instructions need to be turned on. If, however, there are any input data blocks that are neither being generated by prior modules nor are available on the ØPTP, the program needs to turn on additional DMAP instructions in order to generate the required data blocks. The DMAP instructions that need to be so turned on are determined from the File Name Restart Table.

After the additional DMAP instructions are turned on as described in the above paragraph, the process is repeated until it is ensured that all of the required input data blocks are either being generated by prior modules or can be retrieved from ØPTP.

All the DMAP instructions that are turned on as per the above logic (by the use of the File Name Restart Table) are identified and listed in the restart output just after the DMAP source listing.

Those input files or data blocks that are needed for the restart and that are available on the ØPTP are retrieved.

It should be noted that the execution in a modified restart will start at the first module in the DMAP sequence whose execution flag is turned on. Generally, this is before the reentry point.

In the case of modified restarts in the DMAP environment, the effect of changes in the Case Control Deck and/or in the Bulk Data Deck on particular modules cannot be determined since the DMAP itself is, by definition, not predefined. (An MEDT is meaningless for a DMAP.) Hence, it is assumed that the changes will affect the entire DMAP which, therefore, needs to be re-executed. This is accomplished in the program by re-setting the reentry point to zero and treating this case as an unmodified restart. This causes the entire DMAP to be re-executed. Because of this, the need for a modified restart in the DMAP environment is questionable except to reuse a large Bulk Data Deck from the ØPTP.

3.1.4.3 Modified Restart with Rigid Format Switch

This type of restart involves a switch from one rigid format to another. It may or may not involve effective changes to the data in the Case Control Deck and/or in the Bulk Data Deck.

The most important point to recognize in this type of restart is that the reentry point is quite meaningless since it was determined in relation to another rigid format. This is handled in the program by resetting the reentry point to an extremely high value which, for all practical purposes, can be considered to be infinite. As a result, all DMAP instructions in the restart are considered to be before the reentry point and no DMAP instructions are considered to exist after the reentry point.

Once this important change is made, this type of restart is handled in the program in the same manner as a modified restart, with one important modification: the DMAP instructions that are initially turned on are determined not only from the Card Name Researt Table, but also from the Rigid Format Change Restart Table.

3.1.5 Use of DMAP ALTERs in Restarts

Because different types of restarts are handled differently by the program, the user should be careful in the use of DMAP ALTERs in restarts.

In the case of an unmodified restart in which the reentry point is not within a DMAP loop, the only DMAP instructions that are flagged for execution are those that are beyond (and include) the reentry point. Hence, a DMAP ALTER will be flagged for execution only if it is beyond the reentry point and will be ignored if it is before the reentry point.*

In the case of an unmodified restart in which the reentry point is within a DMAP loop, the only DMAP instructions flagged for execution are those that are beyond (and include) the reentry point and those that are before the reentry point but within the DMAP loop. Hence, a DMAP ALTER will be flagged for execution only if it is beyond the reentry point or before it but within the DMAP loop. Otherwise, it will be ignored.*

In the case of a modified restart and a modified restart with rigid format switch, a DMAP ALTER will be flagged for execution regardless of its position in the DMAP with respect to the reentry point.

3.1.6 Rigid Format Output

Although most of the rigid format output is optional, some of the printer output is

* The user can ensure that a DMAP ALTER in an unmodified restart is flagged for execution by suitably deleting the latter part of the restart dictionary so that the reentry point is before the DMAP ALTER. This, of course, will cause more modules to be executed in the restart.

automatic. The printer output is designed for 132 characters per line, with the lines per page controlled by the NLINES keyword on the NASTRAN card (see Section 2.1) and the LINE card in the Case Control Deck (see Section 2.3). The NLINES and LINE default is set to fit on 11-inch paper. Optional titles are printed at the top of each page from information in the Case Control Deck. These titles may be defined at the subcase level. The pages are automatically dated and numbered.

The output from the data recovery and plot modules is all optional, and its selection is controlled by cards in the Case Control Deck. The details of making selections in the Case Control Deck are described in Section 2.3 for printer and punch output, and in Section 4 for plotter output. Since the outputs from the data recovery and plot modules vary considerably with the rigid format, a list of available output is included in the section on the Case Control Deck for each rigid format. Information on the force and stress output available for each element type is given in Section 1.3.

The first part of the output for a NASTRAN run is prepared during the execution of the Preface, prior to the beginning of the DMAP sequence of the rigid format. The following output is either automatically or optionally provided during the execution of the Preface:

1. NASTRAN title page - Two full pages automatic, unless changed with the TITLEØPT keyword on the NASTRAN card (see Section 2.1) before the Executive Control Deck.
2. Executive Control Deck echo - Automatic.
3. Case Control Deck echo - Automatic.
4. Unsorted Bulk Data Deck echo - Optional, selected in Case Control Deck with the ECHØ Card. (Automatic in restart runs and in runs employing the User's Master File, unless suppressed in the Case Control Deck with the ECHØ card).
5. Sorted Bulk Data Deck echo - Automatic, unless suppressed in the Case Control Deck with the ECHØ Card.
6. DMAP listing - Selected with DIAG 14 (or the LIST option on an XDMAP card) in the Executive Control Deck. Provides the list of DMAP instructions, including those resulting from ALTERs, for the subset of the rigid format being executed. (Automatic in restart runs and in runs using the DMAP approach (APP DMAP) or the substructure capability (APP DISP, SUBS), unless suppressed by the NØLIST option on an XDMAP card in the Executive Control Deck.)
7. Checkpoint Dictionary - Automatic, when operating in the checkpoint mode. A printed echo (unless suppressed with the DIAG 9 card in the Executive Control Deck) and the punched cards are prepared for additions to the checkpoint dictionary after the execution of each checkpoint.

When making restarts, the following additional output is automatically prepared during the execution of the Preface:

1. Asterisks (*) are placed beside the DMAP statement numbers of all instructions that are flagged for execution in the restart. (It should be emphasized that a DMAP instruction

marked with the symbol * is only flagged for execution; whether it actually gets executed or not is decided by the logic in the DMAP).

2. Pluses (+) are placed beside the DMAP statement numbers of all instructions that are processed only at DMAP compilation time. (DMAP instructions BEGIN, FILE, LABEL, PRECHK and XDMAP are the only instructions that belong to this category).

3. Message indicating the bit position activated by a rigid format change.

4. Message indicating the type of restart (unmodified, modified or modified with rigid format switch).

5. Table indicating, among other things, the effective data changes (if any) and the associated "packed bit positions" that control the restart. The table distinguishes between effective changes made to the Case Control Deck and those made to the Bulk Data Deck. The reader is referred to the Programmer's Manual for the full interpretation of this table.

6. List of files along with the DMAP instructions that were marked for execution (if any) by the File Name Restart Table.

7. List of files from the Old Problem Tape, including purged files, used to initiate the restart.

A number of fatal errors are detected by the DMAP statements in the various rigid formats. These messages indicate the presence of fatal user errors that either cannot be determined by the functional modules or can be more effectively detected by the DMAP statements in the rigid format. The detection of such an error causes a transfer to a LABEL instruction near the end of the rigid format. The text of the message is output and the execution is terminated. These messages will always appear at the end of the NASTRAN output. The messages applicable to each rigid format are described under the description of that rigid format.

NASTRAN diagnostic messages are usually identified by numbers. These messages may be either program diagnostics or user diagnostics, and they may contain information, warnings, or an indication of a fatal error. There are also a few unnumbered, self-explanatory messages, for example, the time that the execution of each functional module begins and ends.

The Grid Point Singularity Table (GPST) is automatically output following the execution of the Grid Point Singularity Processor (GPSP) if singularities remain in the stiffness matrix at the grid point level. This table contains all possible combinations of single-point constraints, in the global coordinate system, that can be used to remove the singularities. Entries in this table should only be treated as warnings, because it cannot be determined at the grid point level whether or not the singularities are removed by other means, such as general elements or multipoint constraints. Further information on this matter is given in the Theoretical Manual.

Several items of output are discussed in other sections. Output that is not associated with all of the rigid formats is discussed in the sections treating the individual rigid formats. Some

output is under the control of PARAM cards. These items are discussed in Section 2.4 (PARAM card). The DIAG card is used to control the printing of some output. A list of the available output under DIAG control is given in the description of the Executive Control Deck in Section 2.2.

Any of the matrices or tables that are prepared by the functional modules can be printed by using selected utility modules described in Section 5.5. These utility modules can be scheduled at any point in a rigid format by using the ALTER feature. (See Section 3.1.5 for the manner in which ALTERs are handled in restarts.) In general, they should be scheduled immediately after the functional module that generates the table or matrix to be printed. Note that functional modules cannot be separated from a SAVE instruction. However, the user is cautioned to check the calling sequence for the utility module, in order to be certain that all required inputs have been generated prior to this point.

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3.2 STATIC ANALYSIS

3.2.1 DMAP Sequence for Static Analysis

```
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DISPLACEMENT APPROACH, RIGID FORMAT 1

    LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


OPTIONS IN EFFECT   GO     ERR=2   LIST   NODECK   NOREF   NOOSCAR
-----------------

   1 BEGIN     DISP 01 - STATIC ANALYSIS - APR. 1984 $
   2 PRECHK    ALL $
   3 FILE      OPTP2=SAVE/EST1=SAVE $
   4 FILE      QG=APPEND/PGG=APPEND/UGV=APPEND/GM=SAVE/KNN=SAVE $
   5 PARAM     //*MPY*/CARDNO/0/0 $
   6 GP1       GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  NOGPDT/
               ALWAYS=-1 $
   7 PLTTRAN   BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $
   8 GP2       GEOM2,EQEXIN/ECT $
   9 PARAML    PCDB//*PRES*////JUMPPLOT $
  10 PURGE     PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $
  11 COND      P1,JUMPPLOT $
  12 PLTSET    PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/    S,N,
               JUMPPLOT $
  13 PRTMSG    PLTSETX// $
  14 PARAM     //*MPY*/PLTFLG/1/1 $
  15 PARAM     //*MPY*/PFILE/0/0 $
  16 COND      P1,JUMPPLOT $
  17 PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
               NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $
  18 PRTMSG    PLOTX1// $
  19 LABEL     P1 $
  20 GP3       GEOM3,EQEXIN,GEOM2/SLT,GPTT/S,N,NOGRAV/NEVER=1 $
  21 PARAM     //*AND*/NOMGG/NOGRAV/V,Y,GRDPNT=-1 $
  22 TA1       ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/LUSET/S,N,NOSIMP/1/
               S,N,NOGENL/S,N,GENEL $
  23 PARAM     //*AND*/NOELMT/NOGENL/NOSIMP $
  24 COND      ERROR4,NOELMT $
  25 PURGE     KGGX,GPST/NOSIMP/OGPST/GENEL $
  26 OPTPR1    MPT,EPT,ECT,DIT,EST/OPTP1/S,N,PRINT/S,N,TSTART/S,N,COUNT $
  27 LABEL     LOOPTOP $                                      Top of Optimization Loop
  28 COND      LBL1,NOSIMP $
  29 PARAM     //*ADD*/NOKGGX/1/0 $
  30 EQUIV     OPTP1,OPTP2/NEVER/EST,EST1/NEVER $
```


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DISPLACEMENT APPROACH, RIGID FORMAT 1

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```
31  EMG     EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,/S,N,NOKGGX/ S,
            N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/C,Y,CPQUAD1/C,Y,
            CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/  C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,
            CPTRPLT/C,Y,CPTRBSC $
32  COND    JMPKGG,NOKGGX $
33  EMA     GPECT,KDICT,KELM/KGGX,GPST $
34  LABEL   JMPKGG $
35  PURGE   MGG/NOMGG $
36  COND    JMPMGG,NOMGG $
37  EMA     GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $
38  LABEL   JMPMGG $
39  COND    LBL1,GRDPNT $
40  COND    ERROR2,NOMGG $
41  GPWG    BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT/C,Y,WTMASS $
42  OFP     OGPWG,,,,,//S,N,CARDNO $
43  LABEL   LBL1 $
44  EQUIV   KGGX,KGG/NOGENL $
45  COND    LBL11A,NOGENL $
46  SMA3    GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $
47  LABEL   LBL11A $
48  PARAM   //*MPY*/NSKIP/0/0 $
49  LABEL   LBL11 $                              Top of Constraints Loop
50  GP4     CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,YS,USET,ASET/
            LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/S,N,
            NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/ S,Y,
            AUTOSPC $
51  COND    ERROR3,NOL $
52  PARAM   //*AND*/NOSR/SINGLE/REACT $
53  PURGE   KRR,KLR,QR,DM/REACT/GM/MPCF1/GO,KOO,LOO,PO,UOOV,RUOV/OMIT/PS,
            KFS,KSS/SINGLE/QG/NOSR $
54  COND    LBL4,GENEL $
55  PARAM   //*EQ*/GPSPFLG/AUTOSPC/0 $
56  COND    LBL4,GPSPFLG $
57  GPSP    GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
58  OFP     OGPST,,,,,//S,N,CARDNO $
59  LABEL   LBL4 $
60  EQUIV   KGG,KNN/MPCF1 $
61  COND    LBL2,MPCF2 $
62  MCE1    USET,RG/GM $
63  MCE2    USET,GM,KGG,,,/KNN,,, $
64  LABEL   LBL2 $
65  EQUIV   KNN,KFF/SINGLE $
```

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```
 66  COND      LBL3,SINGLE $
 67  SCE1      USET,KNN,,,/KFF,KFS,KSS,,, $
 68  LABEL     LBL3 $
 69  EQUIV     KFF,KAA/OMIT $
 70  COND      LBL5,OMIT $
 71  SMP1      USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
 72  LABEL     LBL5 $
 73  EQUIV     KAA,KLL/REACT $
 74  COND      LBL6,REACT $
 75  RBMG1     USET,KAA,/KLL,KLR,KRR,,, $
 76  LABEL     LBL6 $
 77  RBMG2     KLL/LLL $
 78  COND      LBL7,REACT $
 79  RBMG3     LLL,KLR,KRR/DM $
 80  LABEL     LBL7 $
 81  SSG1      SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,CASECC,DIT,/PG/,,,,/
               LUSET/NSKIP $
 82  EQUIV     PG,PL/NOSET $
 83  COND      LBL10,NOSET $
 84  SSG2      USET,GM,YS,KFS,GO,DM,PG/QR,PO,PS,PL $
 85  LABEL     LBL10 $
 86  SSG3      LLL,KLL,PL,LOO,KOO,PO/ULV,UOOV,RULV,RUOV/OMIT/V,Y,IRES=-1/
               NSKIP/S,N,EPSI $
 87  COND      LBL9,IRES $
 88  MATGPR    GPL,USET,SIL,RULV//*L* $
 89  MATGPR    GPL,USET,SIL,RUOV//*O* $
 90  LABEL     LBL9 $
 91  SDR1      USET,PG,ULV,UOOV,YS,GO,GM,PS,KFS,KSS,QR/UGV,PGG,QG/NSKIP/  *
               STATICS* $
 92  COND      LBL8,REPEAT $
 93  REPT      LBL11,360 $
 94  JUMP      ERROR1 $                          Bottom of Constraints Loop
 95  PARAM     //*NOT*/TEST/REPEAT $
 96  COND      ERROR5,TEST $
 97  LABEL     LBL8 $
 98  GPFDR     CASECC,UGV,KELM,KDICT,ECT,EQEXIN,GPECT,PGG,QG/ONRGY1,OGPFB1/  *
               STATICS* $
 99  OFP       ONRGY1,OGPFB1,,,,//S,N,CARDNO $
100  COND      NONPCF,GRDEQ $
101  EQMCK     CASECC,EQEXIN,GPL,BGPDT,SIL,USET,KGG,GM,UGV,PGG,QG,CSTM/  OQM1/
               V,Y,OPT=0/V,Y,GRDEQ/NSKIP $
102  OFP       OQM1,,,,,//S,N,CARDNO $
```

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DISPLACEMENT APPROACH, RIGID FORMAT 1

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
103  LABEL    NOMPCF $
104  SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QG,UGV,EST,
              XYCDB,PGG/OPG1,OQG1,OUGV1,OES1,OEF1,PUGV1/*STATICS*/S,N,
              NOSORT2/-1/S,N,STRNFLG $
105  COND     LBLSTRS,STRESS $
106  CURV     OES1,MPT,CSTM,EST,SIL,GPL/OES1M,OES1G/V,Y,STRESS/  V,Y,
              NINTPTS $
107  LABEL    LBLSTRS $
108  PURGE    OES1M/STRESS $
109  COND     LBLSTRN,STRNFLG $
110  SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDT,,,UGV,EST,,/ ,,,
              OES1A,,/*STATICS*//1 $
111  COND     LBLSTRN,STRAIN $
112  CURV     OES1A,MPT,CSTM,EST,SIL,GPL/OES1AM,OES1AG/V,Y,STRAIN/   V,Y,
              NINTPTS $
113  LABEL    LBLSTRN $
114  PURGE    OES1A/STRNFLG $
115  COND     LBL17,NOSORT2 $
116  SDR3     OUGV1,OPG1,OQG1,OEF1,OES1,/OUGV2,OPG2,OQG2,OEF2,OES2, $
117  PARAM    //*SUB*/PRTSORT2/NOSORT2/1 $
118  COND     LBLSORT1,PRTSORT2 $
119  OFP      OUGV2,OPG2,OQG2,OEF2,OES2,//S,N,CARDNO $
120  JUMP     LBLXYPLT $
121  LABEL    LBLSORT1 $
122  OFP      OUGV1,OPG1,OQG1,OEF1,OES1,//S,N,CARDNO $
123  LABEL    LBLXYPLT $
124  OFP      OES1M,OES1G,OES1A,OES1AM,OES1AG,//S,N,CARDNO $
125  XYTRAN   XYCDB,OPG2,OQG2,OUGV2,OES2,OEF2/XYPLTT/*TRAN*/*PSET*/S,N,PFILE/
              S,N,CARDNO $
126  XYPLOT   XYPLTT// $
127  JUMP     DPLOT $
128  LABEL    LBL17 $
129  PURGE    OUGV2/NOSORT2 $
130  COND     LBLOFP,COUNT $
131  OPTPR2   OPTP1,OES1,EST/OPTP2,EST1/S,N,PRINT/TSTART/S,N,COUNT/S,N,
              CARDNO $
132  EQUIV    EST1,EST/ALWAYS/OPTP2,OPTP1/ALWAYS $
133  COND     LOOPEND,PRINT $
134  LABEL    LBLOFP $
135  OFP      OUGV1,OPG1,OQG1,OEF1,OES1,//S,N,CARDNO $
136  OFP      OES1M,OES1G,OES1A,OES1AM,OES1AG,//S,N,CARDNO $
137  LABEL    DPLOT $
138  COND     P2,JUMPPLOT $
139  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUGV1,,GPECT,OES1/
              PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $
```

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DISPLACEMENT APPROACH, RIGID FORMAT 1

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
140  PRTMSG    PLOTX2// $
141  LABEL     P2 $
142  LABEL     LOOPEND $
143  COND      FINIS,COUNT $
144  REPT      LOOPTOP,360 $          Bottom of Optimization Loop
145  JUMP      FINIS $
146  LABEL     ERROR1 $
147  PRTPARM   //-1/*STATICS* $
148  LABEL     ERROR2 $
149  PRTPARM   //-2/*STATICS* $
150  LABEL     ERROR3 $
151  PRTPARM   //-3/*STATICS* $
152  LABEL     ERROR4 $
153  PRTPARM   //-4/*STATICS* $
154  LABEL     ERROR5 $
155  PRTPARM   //-5/*STATICS* $
156  LABEL     FINIS $
157  PURGE     DUMMY/ALWAYS $
158  END       $
```

3.2.2 Description of DMAP Operations for Static Analysis

6. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

7. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

8. GP2 generates Element Connection Table with internal indices.

11. Go to DMAP No. 19 if there are no structure plot requests.

12. PLTSET transforms user input into a form used to drive the structure plotter.

13. PRTMSG prints error messages associated with the structure plotter.

16. Go to DMAP No. 19 if no undeformed structure plots are requested.

17. PLØT generates all requested undeformed structure plots.

18. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

20. GP3 generates Static Loads Table and Grid Point Temperature Table.

22. TA1 generates element tables for use in matrix assembly and stress recovery.

24. Go to DMAP No. 152 and print Error Message No. 4 if no elements have been defined.

26. ØPTPR1 performs phase one property optimization and initialization check.

27. Beginning of loop for property optimization.

28. Go to DMAP No. 43 if there are no structural elements.

31. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

32. Go to DMAP No. 34 if no stiffness matrix is to be assembled.

33. EMA assembles stiffness matrix $[K^x_{gg}]$ and Grid Point Singularity Table.

36. Go to DMAP No. 38 if no mass matrix is to be assembled.

37. EMA assembles mass matrix $[M_{gg}]$.

39. Go to DMAP No. 43 if no weight and balance information is requested.

40. Go to DMAP No. 148 and print Error Message No. 2 if no mass matrix exists.

41. GPWG generates weight and balance information.

42. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

44. Equivalence $[K^x_{gg}]$ to $[K_{gg}]$ if no general elements exist.

45. Go to DMAP No. 47 if no general elements exist.

46. SMA3 adds general elements to $[K^x_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

49. Beginning of loop for multiple constraint sets.

50. GP4 generates flags defining members of various displacement sets (USET), forms multipoint constraint equations $[R_g]\{u_g\} = 0$ and forms enforced displacement vector $\{Y_s\}$.

51. Go to DMAP No. 150 and print Error Message No. 3 if no independent degrees of freedom are defined.

54. Go to DMAP No. 59 if general elements are present.

56. Go to DMAP No. 59 if no potential grid point singularities exist.

57. GPSP generates a table of potential grid point singularities.

58. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output ile for printing.

60. Equivalence $[K_{gg}]$ to $[K_{nn}]$ if no multipoint constraints exist.

61. Go to DMAP No. 64 if the MPC set for the current pass is unchanged from that of the previous pass.

62. MCE1 partitions multipoint constraint equations $[R_g] = [R_m | R_n]$ and

    solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

63. MCE2 partitions stiffness matrix

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right]$$

and performs matrix reduction

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m].$$

65. Equivalence $[K_{nn}]$ to $[K_{ff}]$ if no single-point constraints exist.

66. Go to DMAP No. 68 if no single-point constraints exist.

67. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right].$$

69. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

70. Go to DMAP No. 72 if no omitted coordinates exist.

71. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right],$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

73. Equivalence $[K_{aa}]$ to $[K_{\ell\ell}]$ if no free-body supports exist.

74. Go to DMAP No. 76 if no free-body supports exist.

75. RBMG1 partitions out free-body supports

$$[K_{aa}] = \left[\begin{array}{c|c} K_{\ell\ell} & K_{\ell r} \\ \hline K_{r\ell} & K_{rr} \end{array}\right] .$$

77. RBMG2 decomposes constrained stiffness matrix $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$.

78. Go to DMAP No. 80 if no free-body supports exist.

79. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}] \quad ,$$

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D]$$

and calculates rigid body error ratio

$$\varepsilon = \frac{||X||}{||K_{rr}||} \quad .$$

81. SSG1 generates static load vectors $\{P_g\}$.

82. Equivalence $\{P_g\}$ to $\{P_\ell\}$ if no constraints are applied.

83. Go to DMAP No. 85 if no constraints are applied.

84. SSG2 applies constraints to static load vectors

$$\{P_g\} = \left\{\begin{array}{c} \bar{P}_n \\ \hline P_m \end{array}\right\} , \quad \{P_n\} = \{\bar{P}_n\} + [G_m^T]\{P_m\} \quad ,$$

$$\{P_n\} = \left\{\begin{array}{c} \bar{P}_f \\ \hline P_s \end{array}\right\} , \quad \{P_f\} = \{\bar{P}_f\} - [K_{fs}]\{Y_s\} \; ,$$

$$\{P_f\} = \left\{\begin{array}{c} \bar{P}_a \\ \hline P_o \end{array}\right\} , \quad \{P_a\} = \{\bar{P}_a\} + [G_o^T]\{P_o\} \quad ,$$

$$\{P_a\} = \left\{\begin{array}{c} P_\ell \\ \hline P_r \end{array}\right\}$$

and calculates determinate forces of reaction $\{q_r\} = -\{P_r\} - [D^T]\{P_\ell\}$.

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86. SSG3 solves for displacements of independent coordinates

$$\{u_\ell\} = [K_{\ell\ell}]^{-1}\{P_\ell\} \quad ,$$

solves for displacements of omitted coordinates

$$\{u_o^o\} = [K_{oo}]^{-1}\{P_o\} \quad ,$$

calculates residual vector (RULV) and residual vector error ratio for independent coordinates

$$\{\delta P_\ell\} = \{P_\ell\} - [K_{\ell\ell}]\{u_\ell\} \quad ,$$

$$\varepsilon_\ell = \frac{\{u_\ell^T\}\{\delta P_\ell\}}{\{P_\ell^T\}\{u_\ell\}}$$

and calculates residual vector (RUØV) and residual vector error ratio for omitted coordinates

$$\{\delta P_o\} = \{P_o\} - [K_{oo}]\{u_o^o\} \quad ,$$

$$\varepsilon_o = \frac{\{u_o^T\}\{\delta P_o\}}{\{P_o^T\}\{u_o^o\}}$$

87. Go to DMAP No. 90 if residual vectors are not to be printed.

88. MATGPR prints the residual vector for independent coordinates (RULV).

89. MATGPR prints the residual vector for omitted coordinates (RUØV).

91. SDR1 recovers dependent displacements

$$\left\{\begin{array}{c} u_\ell \\ \hline u_r \end{array}\right\} = \{u_a\} \quad , \qquad \{u_o\} = [G_o]\{u_a\} + \{u_o^o\} \quad ,$$

$$\left\{\begin{array}{c} u_a \\ \hline u_o \end{array}\right\} = \{u_f\} \quad , \qquad \left\{\begin{array}{c} u_f \\ \hline Y_s \end{array}\right\} = \{u_n\} \quad ,$$

$$\{u_m\} = [G_m]\{u_n\} \quad , \qquad \left\{\begin{array}{c} u_n \\ \hline u_m \end{array}\right\} = \{u_g\}$$

and recovers single-point forces of constraint

$$\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\} + [K_{ss}]\{Y_s\}.$$

92. Go to DMAP No. 97 if all constraint sets have been processed.

93. Go to DMAP No. 49 if additional sets of constraints need to be processed.

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94. Go to DMAP No. 146 and print Error Message No. 1 as the number of constraint sets exceeds 360.

96. Go to DMAP No. 154 and print Error Message No. 5 if multiple boundary conditions are attempted with an improper subset.

98. GPFDR calculates the grid point force balance (ØGPFB1) and element strain energy (ØNRGY1) for requested sets.

99. ØFP formats the tables prepared by GPFDR and places them on the system output file for printing.

100. Go to DMAP No. 103 if no multipoint constraint force balance is requested.

101. EQMCK calculates the force and moment equilibrium check and prepares the multipoint constraint force balance (ØQM1) for output.

102. ØFP formats the table prepared by EQMCK and places it on the system output file for printing.

104 SDR2 calculates the element forces (ØEF1) and stresses (ØES1) and prepares load vectors (ØPG1), displacement vectors (ØUGV1) and single-point forces of constraint (ØQG1) for output and translation components of the displacement vectors (PUGV1).

105. Go to DMAP No. 107 if element stresses in material coordinate system and stresses at the connected grid points are not to be calculated.

106. CURV calculates element stresses in material coordinate system (ØES1M) and stresses at the connected grid points (ØES1G).

109. Go to DMAP No. 113 if element strains/curvatures are not to be calculated.

110. SDR2 calculates element strains/curvatures (ØES1A).

111. Go to DMAP No. 113 if element strains/curvatures in material coordinate system and strains/curvatures at the connected grid points are not to be calculated.

112. CURV calculates element strains/curvatures in material coordinate system (ØES1AM) and strains/curvatures at the connected grid points (ØES1AG).

115. Go to DMAP No. 128 if there are no requests for output sorted by grid point number or element number.

116. SDR3 prepares requested output sorted by grid point number of element number.

118. Go to DMAP No. 121 if printed output sorted by grid point number or element number is not required.

119. ØFP formats the tables prepared by SDR3 for output sorted by grid point number or element number and places them on the system output file for printing.

120. Go to DMAP No. 123.

122. ØFP formats the tables prepared by SDR2 for output sorted by subcase number and places them on the system output file for printing.

124. ØFP formats the tables prepared by CURV and SDR2 for output sorted by subcase number and places them on the system output file for printing.

125. XYTRAN prepares the input for requested X-Y plots.

126. XYPLØT prepares the requested X-Y plots of displacements, forces, stresses, loads and single-point forces of constraint vs. subcase.

127. Go to DMAP No. 137.

130. Go to DMAP No. 134 if no phase two property optimization.

131. ØPTPR2 performs phase two property optimization.

132. Equivalence EST1 to EST and ØPTP2 to ØPTP1.

133. Go to DMAP No. 142 if no additional output is to be printed for this loop.

135. ØFP formats the tables prepared by SDR2 for output sorted by subcase number and places them on the system output file for printing.

136. ØFP formats the tables prepared by CURV and SDR2 for output sorted by subcase number and places them on the system output file for printing.

138. Go to DMAP No. 141 if no deformed structure plots are requested.

139. PLØT generates all requested deformed structure and contour plots.

140. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.

143. Go to DMAP No. 156 and make normal exit if property optimization is complete.

144. Go to DMAP No. 27 if additional loops for property optimization are needed.

145. Go to DMAP No. 156 and make normal exit.

147. Print Error Message No. 1 and terminate execution.

149. Print Error Message No. 2 and terminate execution.

151. Print Error Message No. 3 and terminate execution.

153. Print Error Message No. 4 and terminate execution.

155. Print Error Message No. 5 and terminate execution.

3.2.3 Output for Static Analysis

The following printed output, sorted by loads (SØRT1) or by grid point number or element number (SØRT2), may be requested for Static Analysis solutions:

1. Displacements and components of static loads and single-point forces of constraint at selected grid points or scalar points.
2. Forces and stresses in selected elements.
3. Strains/curvatures in selected elements (only for TRIA1, TRIA2, QUAD1 and QUAD2 elements).

The following plotter output may be requested:

1. Undeformed and deformed plots of the structural model.
2. Contour plots of stresses and displacements.
3. X-Y plot of any component of displacement, static load, or single-point force of constraint for a grid point or scalar point versus subcase.
4. X-Y plot of any stress or force component for an element versus subcase.

3.2.4 Case Control Deck for Static Analysis

The following items relate to subcase definition and data selection for Static Analysis:

1. A separate subcase must be defined for each unique combination of constraints and static loads.
2. A static loading condition must be defined for (not necessarily within) each subcase with a LØAD, TEMPERATURE(LØAD), or DEFØRM selection unless all loading is specified with grid point displacements on SPC cards.
3. An SPC set must be selected for (not necessarily within) each subcase, unless the model is a properly supported free body, or all constraints are specified on GRID cards, Scalar Connection cards, or with General Elements.
4. Loading conditions associated with the same sets of constraints should be in contiguous subcases in order to avoid unnecessary looping.
5. REPCASE may be used to repeat subcases in order to allow multiple sets of the same output item.

3.2.5 Parameters for Static Analysis

The following parameters are used in Static Analysis:

1. GRDPNT - optional. A positive integer value of this parameter will cause the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed.
2. WTMASS - optional. The terms of the mass matrix are multiplied by the real value of this parameter when they are generated in EMA.
3. IRES - optional. A positive integer value of this parameter will cause the printing of the residual vectors following the execution of SSG3.
4. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters will cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
5. ØPT - optional. A positive integer value of this parameter causes both equilibrium and multipoint constraint forces to be calculated for the Case Control output request, MPCFØRCE. A negative integer value of this parameter causes only the equilibrium force balance to be calculated for the output request. The default value is 0 which causes only the multipoint constraint forces to be calculated for the output request.
6. GRDEQ - optional. A positive integer value of this parameter selects the grid point about which equilibrium will be checked for the Case Control output request, MPCFØRCE. If the integer value is zero, the basic origin is used. Default is -1.
7. STRESS - optional. This parameter controls the transformation of element stresses to the material coordinate system (only for TRIA1, TRIA2, QUAD1 and QUAD2 elements). If it is a positive integer, the stresses for these elements are transformed to the material coordinate system. If it is zero, stresses at the connected grid points are also computed in addition to the element stresses in the material coordinate system. A negative integer value results in no transformation of the stresses. The default value is -1.
8. STRAIN - optional. This parameter controls the transformation of element strains/curvatures to the material coordinate system (only for TRIA1, TRIA2, QUAD1 and QUAD2 elements). If it is a positive integer, the strains/curvatures for these elements are transformed to the material coordinate system. If it is zero, strains/curvatures at the connected grid points are also computed in addition to the element

strains/curvatures in the material coordinate system. A negative integer value results in no transformation of the strains/curvatures. The default value is -1.

9. NINTPTS - optional. A positive integer value of this parameter specifies the number of closest independent points to be used in the interpolation for computing stresses or strains/curvatures at grid points (only for TRIA1, TRIA2, QUAD1 and QUAD2 elements). A negative integer value or 0 specifies that all independent points are to be used in the interpolation. The default value is 0.

10. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.

11. AUTØSPC - reserved for future optional use. The default value is -1.

3.2.6 Automatic ALTERs for Automated Multi-stage Substructuring

The following lines of the Static Analysis, Rigid Format 1, are ALTERed for automated substructure analyses.

Phase 1: 5, 51, 73-80, 82-142

Phase 2: 5, 6-6, 9-19, 23-24, 30-30, 44-47, 54-59, 98-142

Phase 3: 73-80, 83-90, 91

If APP DISP, SUBS is used, the user may also specify ALTERs. However, these must not interfere with the automatically generated DMAP statement ALTERs listed above. See Section 5.9 for a description and listing of the ALTERs which are automatically generated for substructuring.

3.2.7 Rigid Format Error Messages from Static Analysis

The following fatal errors are detected by the DMAP statements in the Static Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

STATIC ANALYSIS ERRØR MESSAGE NØ. 1 - ATTEMPT TØ EXECUTE MØRE THAN 360 LØØPS.

An attempt has been made to use more than 360 different sets of boundary conditions or more than 360 passes in the optimization loop have been attempted. This number may be increased by ALTERing the REPT instruction following SDR1 in the former case and the REPT instruction following the last PRTMSG instruction in the latter case.

STATIC ANALYSIS ERRØR MESSAGE NØ. 2 - MASS MATRIX REQUIRED FØR WEIGHT AND BALANCE CALCULATIØNS.

The mass matrix is null because either no elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

STATIC ANALYSIS ERRØR MESSAGE NØ. 3 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, SUPØRT, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

STATIC ANALYSIS ERRØR MESSAGE NØ. 4 - NØ ELEMENTS HAVE BEEN DEFINED.

No elements have been defined with either Connection cards or GENEL cards.

STATIC ANALYSIS ERRØR MESSAGE NØ. 5 - A LØØPING PRØBLEM RUN ØN A NØN-LØØPING SUBSET.

A problem requiring boundary condition changes was run on subset 1 or 3. The problem should be restarted on subset 0.

3.3 STATIC ANALYSIS WITH INERTIA RELIEF

3.3.1 DMAP Sequence for Static Analysis with Inertia Relief

```
RIGID FORMAT DMAP LISTING
RELEASE APR. 1984

DISPLACEMENT APPROACH, RIGID FORMAT 2

    LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


OPTIONS IN EFFECT   GO      ERR=2   LIST    NODECK  NOREF   NOOSCAR

    1  BEGIN     DISP 02 - STATIC ANALYSIS WITH INERTIA RELIEF - APR. 1984 $
    2  PRECHK    ALL $
    3  FILE      QG=APPEND/PGG=APPEND/UGV=APPEND/GM=SAVE/KNN=SAVE/MNN=SAVE $
    4  PARAM     //*MPY*/CARDNO/0/0 $
    5  GP1       GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  NOGPDT/
                 ALWAYS=-1 $
    6  PLTTRAN   BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $
    7  GP2       GEOM2,EQEXIN/ECT $
    8  PARAML    PCDB//*PRES*////JUMPPLOT $
    9  PURGE     PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $
   10  COND      P1,JUMPPLOT $
   11  PLTSET    PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/   S,N,
                 JUMPPLOT $
   12  PRTMSG    PLTSETX// $
   13  PARAM     //*MPY*/PLTFLG/1/1 $
   14  PARAM     //*MPY*/PFILE/0/0 $
   15  COND      P1,JUMPPLOT $
   16  PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
                 NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $
   17  PRTMSG    PLOTX1// $
   18  LABEL     P1 $
   19  GP3       GEOM3,EQEXIN,GEOM2/SLT,GPTT/NOGRAV $
   20  TA1       ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/LUSET/S,N,NOSIMP/1/
                 S,N,NOGENL/S,N,GENEL $
   21  COND      ERROR6,NOSIMP $
   22  PURGE     OGPST/GENEL $
   23  PARAM     //*ADD*/NOKGGX/1/0 $
   24  PARAM     //*ADD*/NOMGG/1/0 $
   25  EMG       EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,/S,N,NOKGGX/ S,
                 N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/C,Y,CPQUAD1/C,Y,
                 CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/  C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,
                 CPTRPLT/C,Y,CPTRBSC $
   26  PURGE     KGGX,GPST/NOKGGX $
   27  COND      JMPKGG,NOKGGX $
   28  EMA       GPECT,KDICT,KELM/KGGX,GPST $
   29  LABEL     JMPKGG $
```


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RIGID FORMAT DMAP LISTING
RELEASE APR. 1984

DISPLACEMENT APPROACH, RIGID FORMAT 2

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
30  COND     ERROR1,NOMGG $
31  EMA      GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $
32  COND     LGPWG,GRDPNT $
33  GPWG     BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $
34  OFP      OGPWG,,,,,//S,N,CARDNO $
35  LABEL    LGPWG $
36  EQUIV    KGGX,KGG/NOGENL $
37  COND     LBL11A,NOGENL $
38  SMA3     GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $
39  LABEL    LBL11A $
40  PARAM    //*MPY*/NSKIP/0/0 $
-------------------------------------------- Top of Constraints Loop
41  LABEL    LBL11 $
42  GP4      CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,YS,USET,ASET/
             LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/S,N,
             NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/ S,Y,
             AUTOSPC $
43  COND     ERROR3,NOL $
44  COND     ERROR4,REACT $
45  PURGE    GM/MPCF1/GO,KOO,LOO,MOO,MOA,PO,UOOV,RUOV/OMIT/KSS,KFS,PS/
             SINGLE $
46  COND     LBL4,GENEL $
47  PARAM    //*EQ*/GPSPFLG/AUTOSPC/0 $
48  COND     LBL4,GPSPFLG $
49  GPSP     GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
50  OFP      OGPST,,,,,//S,N,CARDNO $
51  LABEL    LBL4 $
52  EQUIV    KGG,KNN/MPCF1/MGG,MNN/MPCF1 $
53  COND     LBL2,MPCF2 $
54  MCE1     USET,RG/GM $
55  MCE2     USET,GM,KGG,MGG,,/KNN,MNN,, $
56  LABEL    LBL2 $
57  EQUIV    KNN,KFF/SINGLE/MNN,MFF/SINGLE $
58  COND     LBL3,SINGLE $
59  SCE1     USET,KNN,MNN,,/KFF,KFS,KSS,MFF,, $
60  LABEL    LBL3 $
61  EQUIV    KFF,KAA/OMIT/ MFF,MAA/OMIT $
62  COND     LBL5,OMIT $
63  SMP1     USET,KFF,MFF,,/GO,KAA,KOO,LOO,MAA,MOO,MOA,, $
64  LABEL    LBL5 $
```

```
RIGID FORMAT DMAP LISTING
RELEASE APR. 1984

DISPLACEMENT APPROACH, RIGID FORMAT 2

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

 65  RBMG1     USET,KAA,MAA/KLL,KLR,KRR,MLL,MLR,MRR $
 66  RBMG2     KLL/LLL $
 67  RBMG3     LLL,KLR,KRR/DM $
 68  RBMG4     DM,MLL,MLR,MRR/MR $
 69  SSG1      SLT,BGPDT,CSTM,SIL,EST ,MPT,GPTT,EDT,MGG,CASECC,DIT,/PG,,,,/
               LUSET/NSKIP $
 70  SSG2      USET,GM,YS,KFS,GO,DM,PG/QR,PO,PS,PL $
 71  SSG4      PL,QR,PO,MR,MLR,DM,MLL,MOO,MOA,GO,USET/PLI,POI/OMIT $
 72  SSG3      LLL,KLL,PLI,LOO,KOO,POI/ULV,UOOV,RULV,RUOV/OMIT/V,Y,    IRES=-1/
               NSKIP/S,N,EPSI $
 73  COND      LBL9,IRES $
 74  MATGPR    GPL,USET,SIL,RULV//*L* $
 75  MATGPR    GPL,USET,SIL,RUOV//*O* $
 76  LABEL     LBL9 $
 77  SDR1      USET,PG,ULV,UOOV,YS,GO,GM,PS,KFS,KSS,QR/UGV,PGG,QG/NSKIP/   *
               STATICS* $
 78  COND      LBL8,REPEAT $
 79  REPT      LBL11,360 $
_____________________________________________  Bottom of Constraints Loop
 80  JUMP      ERROR2 $
 81  PARAM     //*NOT*/TEST/REPEAT $
 82  COND      ERROR5,TEST $
 83  LABEL     LBL8 $
 84  COND      NOMPCF,GRDEQ $
 85  EQMCK     CASECC,EQEXIN,GPL,BGPDT,SIL,USET,KGG,GM,UGV,PGG,QG,CSTM/   OQM1/
               V,Y,OPT=0/V,Y,GRDEQ/NSKIP $
 86  OFP       OQM1,,,,,//S,N,CARDNO $
 87  LABEL     NOMPCF $
 88  SDR2      CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QG,UGV,EST,,PGG/
               OPG1,OQG1,OUGV1,OES1,OEF1,PUGV1/*STATICS* $
 89  OFP       OUGV1,OPG1,OQG1,OEF1,OES1,//S,N,CARDNO $
 90  COND      P2,JUMPPLOT $
 91  PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUGV1,,GPECT,OES1/
               PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $
 92  PRTMSG    PLOTX2// $
 93  LABEL     P2 $
 94  JUMP      FINIS $
 95  LABEL     ERROR1 $
 96  PRTPARM   //-1/*INERTIA* $
 97  LABEL     ERROR2 $
 98  PRTPARM   //-2/*INERTIA* $
 99  LABEL     ERROR3 $
100  PRTPARM   //-3/*INERTIA* $
101  LABEL     ERROR4 $
```

RIGID FORMAT DMAP LISTING
RELEASE APR. 1984

DISPLACEMENT APPROACH, RIGID FORMAT 2

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
102 PRTPARM  //-4/*INERTIA* $
103 LABEL    ERROR5 $
104 PRTPARM  //-5/*INERTIA* $
105 LABEL    ERROR6 $
106 PRTPARM  //-6/*INERTIA* $
107 LABEL    FINIS $
108 PURGE    DUMMY/ALWAYS $
109 END      $
```

3.3.2 Description of DMAP Operations for Static Analysis with Inertia Relief

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

7. GP2 generates Element Connection Table with internal indices.

10. Go to DMAP No. 18 if there are no structure plot requests.

11. PLTSET transforms user input into a form used to drive the structure plotter.

12. PRTMSG prints error messages associated with the structure plotter.

15. Go to DMAP No. 18 if no undeformed structure plots are requested.

16. PLØT generates all requested undeformed structure plots.

17. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

19. GP3 generates Static Loads Table and Grid Point Temperature Table.

20. TA1 generates element tables for use in matrix assembly and stress recovery.

21. Go to DMAP No. 105 and print Error Message No. 6 if there are no structural elements.

25. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

27. Go to DMAP No. 29 if no stiffness matrix is to be assembled.

28. EMA assembles stiffness matrix $[K^x_{gg}]$ and Grid Point Singularity Table.

30. Go to DMAP No. 95 and print Error Message No. 1 if no mass matrix is to be assembled.

31. EMA assembles mass matrix $[M_{gg}]$.

32. Go to DMAP No. 35 if no weight and balance information is requested.

33. GPWG generates weight and balance information.

34. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

36. Equivalence $[K^x_{gg}]$ to $[K_{gg}]$ if no general elements exist.

37. Go to DMAP No. 39 if no general elements exist.

38. SMA3 adds general elements to $[K^x_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

41. Beginning of loop for multiple constraint sets.

42. GP4 generates flags defining members of various displacement sets (USET), forms multipoint constraint equations $[R_g]\{u_g\} = 0$ and forms enforced displacement vector $\{Y_s\}$.

43. Go to DMAP No. 99 and print Error Message No. 3 if no independent degrees of freedom are defined.

44. Go to DMAP No. 101 and print Error Message No. 4 if no free-body supports exist.

46. Go to DMAP No. 51 if general elements are present.

48. Go to DMAP No. 51 if no potential grid point singularities exist.

49. GPSP generates a table of potential grid point singularities.

50. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

52. Equivalence $[K_{gg}]$ to $[K_{nn}]$ and $[M_{gg}]$ to $[M_{nn}]$ if no multipoint constraints exist.

53. Go to DMAP No. 56 if the MPC set for the current pass is unchanged from that of the previous pass.

54. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

55. MCE2 partitions stiffness and mass matrices

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right] \quad \text{and} \quad [M_{gg}] = \left[\begin{array}{c|c} \bar{M}_{nn} & M_{nm} \\ \hline M_{mn} & M_{mm} \end{array}\right]$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \text{ and}$$

$$[M_{nn}] = [\bar{M}_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m].$$

57. Equivalence $[K_{nn}]$ to $[K_{ff}]$ and $[M_{nn}]$ to $[M_{ff}]$ if no single-point constraints exist.

58. Go to DMAP No. 60 if no single-point constraints exist.

59. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right] \quad \text{and} \quad [M_{nn}] = \left[\begin{array}{c|c} M_{ff} & M_{fs} \\ \hline M_{sf} & M_{ss} \end{array}\right].$$

61. Equivalence $[K_{ff}]$ to $[K_{aa}]$ and $[M_{ff}]$ to $[M_{aa}]$ if no omitted coordinates exist.

62. Go to DMAP No. 64 if no omitted coordinates exist.

63. SMP1 partitions constrained stiffness and mass matrices

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right] \quad \text{and} \quad [M_{ff}] = \left[\begin{array}{c|c} \bar{M}_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right],$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reductions $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$

and $$[M_{aa}] = [\bar{M}_{aa}] + [M_{oa}^T][G_o] + [G_o^T][M_{oa}] + [G_o^T][M_{oo}][G_o] .$$

65. RBMG1 partitions out free-body supports

$$[K_{aa}] = \left[\begin{array}{c|c} K_{\ell\ell} & K_{\ell r} \\ \hline K_{r\ell} & K_{rr} \end{array}\right] \quad \text{and} \quad [M_{aa}] = \left[\begin{array}{c|c} M_{\ell\ell} & M_{\ell r} \\ \hline M_{r\ell} & M_{rr} \end{array}\right] .$$

66. RBMG2 decomposes constrained stiffness matrix $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$.

67. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}] ,$$

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D]$$

and calculates rigid body error ratio

$$\epsilon = \frac{||X||}{||K_{rr}||}$$

68. RBMG4 forms rigid body mass matrix

$$[m_r] = [M_{rr}] + [M_{\ell r}^T][D] + [D^T][M_{\ell r}] + [D^T][M_{\ell\ell}][D].$$

69. SSG1 generates static load vectors $\{P_g\}$.

70. SSG2 applies constraints to static load vectors

$$\{P_g\} = \left\{\begin{array}{c} \bar{P}_n \\ \hline P_m \end{array}\right\} , \quad \{P_n\} = \{\bar{P}_n\} + [G_m^T]\{P_m\} ,$$

$$\{P_n\} = \left\{\begin{array}{c} \bar{P}_f \\ \hline P_s \end{array}\right\} , \quad \{P_f\} = \{\bar{P}_f\} - [K_{fs}]\{Y_s\} ,$$

$$\{P_f\} = \left\{\begin{array}{c} \bar{P}_a \\ \hline P_o \end{array}\right\} , \quad \{P_a\} = \{\bar{P}_a\} + [G_o^T]\{P_o\} ,$$

$$\{P_a\} = \left\{\begin{array}{c} P_\ell \\ \hline P_r \end{array}\right\}$$

and calculates determinate forces of reaction $\{q_r\} = -\{P_r\} - [D^T]\{P_\ell\}$.

71. SSG4 calculates inertia loads and combines them with static loads

$$\{P_\ell^i\} = \{P_\ell\} + \left([M_{\ell\ell}][D] + [M_{\ell r}]\right)[m_r]^{-1}\{q_r\} \quad \text{and}$$

$$\{P_o^i\} = \{P_o\} + \left([M_{oo}][G_o] + [M_{ao}^T]\right)\begin{bmatrix} D \\ \hline I \end{bmatrix}[m_r]^{-1}\{q_r\} \ .$$

72. SSG3 solves for displacements of independent coordinates

$$\{u_\ell\} = [K_{\ell\ell}]^{-1}\{P_\ell^i\} \quad ,$$

solves for displacements of omitted coordinates

$$\{u_o^o\} = [K_{oo}]^{-1}\{P_o^i\} \quad ,$$

calculates residual vector (RULV) and residual vector error ratio for independent coordinates

$$\{\delta P_\ell^i\} = \{P_\ell^i\} - [K_{\ell\ell}]\{u_\ell\}$$

$$\varepsilon_\ell = \frac{\{u_\ell^T\}\{\delta P_\ell^i\}}{\{P_\ell^i\}^T\{u_\ell\}}$$

and calculates residual vector (RUØV) and residual vector error ratio for omitted coordinates

$$\{\delta P_o^i\} = \{P_o^i\} - [K_{oo}]\{u_o^o\} \quad ,$$

$$\varepsilon_o = \frac{\{u_o^T\}\{\delta P_o^i\}}{\{P_o^i\}^T\{u_o^o\}} \ .$$

73. Go to DMAP No. 76 if residual vectors are not to be printed.

74. MATGPR prints the residual vector for independent coordinates (RULV).

75. MATGPR prints the residual vector for omitted coordinates (RUØV).

77. SDR1 recovers dependent displacements

$$\left\{\begin{array}{c} u_\ell \\ \hline u_r \end{array}\right\} = \{u_a\} \ , \qquad \{u_o\} = [G_o]\{u_a\} + \{u_o^o\} \quad ,$$

$$\left\{\begin{array}{c} u_a \\ \hline u_o \end{array}\right\} = \{u_f\} \ , \qquad \left\{\begin{array}{c} u_f \\ \hline Y_s \end{array}\right\} = \{u_n\} \quad ,$$

$$\{u_m\} = [G_m]\{u_n\} \ , \quad \left\{\begin{array}{c} u_n \\ \hline u_m \end{array}\right\} = \{u_g\}$$

and recovers single-point forces of constraint

$$\{q_s\} = -\{P_s\} + [K_{fs}^T] \{u_f\} + [K_{ss}] \{Y_s\} .$$

78. Go to DMAP No. 83 if all constraint sets have been processed.

79. Go to DMAP No. 41 if additional sets of constraints need to be processed.

80. Go to DMAP No. 97 and print Error Message No. 2 as the number of constraint sets exceeds 360.

82. Go to DMAP No. 103 and print Error Message No. 5 if multiple boundary conditions are attempted with an improper subset.

84. Go to DMAP No. 87 if no multipoint constraint force balance is requested.

85. EQMCK calculates the force and moment equilibrium check and prepares the multipoint constraint force balance (ØQM1) for output.

86. ØFP formats the table prepared by EQMCK and places it on the system output file for printing.

88. SDR2 calculates element forces (ØEF1) and stresses (ØES1) and prepares load vectors (ØPG1), displacement vectors (ØUGV1), and single-point forces of constraint (ØQG1) for output and translation components of the displacement vector (PUGV1).

89. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

90. Go to DMAP No. 93 if no deformed structure plots are requested.

91. PLØT generates all requested deformed structure and contour plots.

92. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.

94. Go to DMAP No. 107 and make normal exit.

96. Print Error Message No. 1 and terminate execution.

98. Print Error Message No. 2 and terminate execution.

100. Print Error Message No. 3 and terminate execution.

102. Print Error Message No. 4 and terminate execution.

104. Print Error Message No. 5 and terminate execution.

106. Print Error Message No. 6 and terminate execution.

3.3.3 Output for Static Analysis with Inertia Relief

The following output may be requested for Static Analysis with Inertia Relief:

1. Displacements at selected grid points due to the sum of the applied loads and the inertia loads.
2. Nonzero components of the applied static loads at selected grid points.
3. Reactions on free-body supports due to applied loads (single-point forces of constraint).
4. Forces and stresses in selected elements due to the sum of the applied loads and inertia loads.
5. Undeformed and deformed plots of the structural model.
6. Contour plots of stresses and displacements.

3.3.4 Case Control Deck for Static Analysis with Inertia Relief

The following items relate to subcase definition and data selection for Static Analysis with Inertia Relief:

1. A separate subcase must be defined for each unique combination of constraints and static loads.
2. A static loading condition must be defined for (not necessarily within) each subcase with a LØAD selection.
3. An SPC set may be selected only if used to remove grid point singularities or some, but not all, of the free body motions. At least one free body support must be provided with a SUPØRT card in the Bulk Data Deck.
4. Loading conditions associated with the same sets of constraints should be in contiguous subcases in order to avoid unnecessary looping.
5. REPCASE may be used to repeat subcases in order to allow multiple sets for the same output item.

3.3.5 Parameters for Static Analysis with Inertia Relief

The following parameters are used in Static Analysis with Inertia Relief:

1. GRDPNT - optional. A positive integer value of this parameter will cause the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed.

2. WTMASS - optional. The terms of the mass matrix are multiplied by the real value of this parameter when they are generated in EMA.

3. IRES - optional. A positive integer value of this parameter will cause the printing of the residual vectors following the execution of SSG3.

4. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters will cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.

5. ØPT - optional. A positive integer value of this parameter causes both equilibrium and multipoint constraint forces to be calculated for the Case Control output request, MPCFØRCE. A negative integer value of this parameter causes only the equilibrium force balance to be calculated for the output request. The default value is 0 which causes only the multipoint constraint forces to be calculated for the output request.

6. GRDEQ - optional. A positive integer value of this parameter selects the grid point about which equilibrium will be checked for the Case Control output request, MPCFØRCE. If the integer value is zero, the basic origin is used. Default is -1.

7. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.

8. AUTØSPC - reserved for future optional use. The default value is -1.

3.3.6 Automatic ALTERs for Automated Multi-stage Substructuring

The following lines of the Static Analysis with Inertia Relief, Rigid Format 2, are ALTERed in automated substructure analyses.

Phase 1: 4, 44-44, 65-68, 70-94

Phase 2: 4, 5-5, 8-18, 21-21, 30-30, 36-39, 46-51, 84-96

Phase 3: 65-68, 70-76, 77

If APP DISP, SUBS is used, the user may also specify ALTERs. However, these must not interfere with the automatically generated DMAP statement ALTERs listed above. See Section 5.9 for a description and listing of the ALTERs which are automatically generated for substructuring.

3.3.7 Rigid Format Error Messages from Static Analysis with Inertia Relief

The following fatal errors are detected by the DMAP statements in the Static Analysis with Inertia Relief rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

STATIC ANALYSIS WITH INERTIA RELIEF ERRØR MESSAGE NØ. 1 - MASS MATRIX REQUIRED FØR CALCULATIØN ØF INERTIA LØADS.

The mass matrix is null because either no elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

STATIC ANALYSIS WITH INERTIA RELIEF ERRØR MESSAGE NØ. 2 - ATTEMPT TØ EXECUTE MØRE THAN 360 LØØPS.

An attempt has been made to use more than 360 different sets of boundary conditions. This number may be increased by ALTERing the REPT instruction following SDR1.

STATIC ANALYSIS WITH INERTIA RELIEF ERRØR MESSAGE NØ. 3 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, SUPØRT, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

STATIC ANALYSIS WITH INERTIA RELIEF ERRØR MESSAGE NØ. 4 - FREE-BØDY SUPPØRTS ARE REQUIRED.

A statically determinate set of supports must be specified on a SUPØRT card in order to determine the rigid body characteristics of the structural model.

STATIC ANALYSIS WITH INERTIA RELIEF ERRØR MESSAGE NØ. 5 - A LØØPING PRØBLEM RUN ØN A NØN-LØØPING SUBSET.

A problem requiring boundary condition changes was run on subset 1 or 3. The problem should be restarted on subset 0.

STATIC ANALYSIS WITH INERTIA RELIEF ERRØR MESSAGE NØ. 6 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

3.4 NORMAL MODE ANALYSIS

3.4.1 DMAP Sequence for Normal Mode Analysis

```
RIGID FORMAT DMAP LISTING
RELEASE APR. 1984

DISPLACEMENT APPROACH, RIGID FORMAT 3

    LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

OPTIONS IN EFFECT  GO     ERR=2   LIST    NODECK  NOREF   NOOSCAR
-----------------

  1 BEGIN    DISP 03 - NORMAL MODES ANALYSIS - APR. 1984 $
  2 PRECHK   ALL $
  3 FILE     LAMA=APPEND/PHIA=APPEND $
  4 PARAM    //*MPY*/CARDNO/0/0 $
  5 GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  NOGPDT/
             ALWAYS=-1 $
  6 PLTTRAN  BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $
  7 GP2      GEOM2,EQEXIN/ECT $
  8 PARAML   PCDB//*PRES*////JUMPPLOT $
  9 PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $
 10 COND     P1,JUMPPLOT $
 11 PLTSET   PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/   S,N,
             JUMPPLOT $
 12 PRTMSG   PLTSETX// $
 13 PARAM    //*MPY*/PLTFLG/1/1 $
 14 PARAM    //*MPY*/PFILE/0/0 $
 15 COND     P1,JUMPPLOT $
 16 PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
             NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $
 17 PRTMSG   PLOTX1//$
 18 LABEL    P1 $
 19 GP3      GEOM3,EQEXIN,GEOM2/,GPTT/NOGRAV $
 20 TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/LUSET/S,N,NOSIMP/1/
             S,N,NOGENL/S,N,GENEL $
 21 COND     ERROR4,NOSIMP $
 22 PURGE    OGPST/GENEL $
 23 PARAM    //*ADD*/NOKGGX/1/0 $
 24 PARAM    //*ADD*/NOMGG/1/0 $
 25 EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,/S,N,NOKGGX/ S,
             N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/C,Y,CPQUAD1/C,Y,
             CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/  C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,
             CPTRPLT/C,Y,CPTRBSC $
 26 PURGE    KGGX,GPST/NOKGGX $
 27 COND     JMPKGG,NOKGGX $
 28 EMA      GPECT,KDICT,KELM/KGGX,GPST $
 29 LABEL    JMPKGG $
```

RIGID FORMAT DMAP LISTING
RELEASE APR. 1984

DISPLACEMENT APPROACH, RIGID FORMAT 3

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
30  COND    ERROR1,NOMGG $
31  EMA     GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $
32  COND    LGPWG,GRDPNT $
33  GPWG    BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $
34  OFP     OGPWG,,,,,//S,N,CARDNO $
35  LABEL   LGPWG $
36  EQUIV   KGGX,KGG/NOGENL $
37  COND    LBL11,NOGENL $
38  SMA3    GE1,KGGX/KGG/LUSET/NOGENL/NOSIMP $
39  LABEL   LBL11 $
40  PARAM   //*MPY*/NSKIP/0/0 $
41  GP4     CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,YS,USET,ASET/
            LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/S,N,
            NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/ S,Y,
            AUTOSPC $
42  COND    ERROR3,NOL $
43  PURGE   KRR,KLR,DM,MLR,MR/REACT/GM/MPCF1/GO/OMIT/KFS/SINGLE/QG/NOSET $
44  COND    LBL4,GENEL $
45  PARAM   //*EQ*/GPSPFLG/AUTOSPC/0 $
46  COND    LBL4,GPSPFLG $
47  GPSP    GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
48  OFP     OGPST,,,,,//S,N,CARDNO $
49  LABEL   LBL4 $
50  EQUIV   KGG,KNN/MPCF1/MGG,MNN/MPCF1 $
51  COND    LBL2,MPCF1 $
52  MCE1    USET,RG/GM $
53  MCE2    USET,GM,KGG,MGG,,/KNN,MNN,, $
54  LABEL   LBL2 $
55  EQUIV   KNN,KFF/SINGLE/MNN,MFF/SINGLE $
56  COND    LBL3,SINGLE $
57  SCE1    USET,KNN,MNN,,/KFF,KFS,,MFF,, $
58  LABEL   LBL3 $
59  EQUIV   KFF,KAA/OMIT $
60  EQUIV   MFF,MAA/OMIT $
61  COND    LBL5,OMIT $
62  SMP1    USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
63  SMP2    USET,GO,MFF/MAA $
64  LABEL   LBL5 $
```

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OF POOR QUALITY

RIGID FORMAT DMAP LISTING
RELEASE APR. 1984

DISPLACEMENT APPROACH, RIGID FORMAT 3

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
 65  COND      LBL6,REACT $
 66  RBMG1     USET,KAA,MAA/KLL,KLR,KRR,MLL,MLR,MRR $
 67  RBMG2     KLL/LLL $
 68  RBMG3     LLL,KLR,KRR/DM $
 69  RBMG4     DM,MLL,MLR,MRR/MR $
 70  LABEL     LBL6 $
 71  DPD       DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,,,,,,,EED,EQDYN/  LUSET/
               LUSETD/NOTFL/NODLT/NOPSDL/NOFRL/  NONLFT/NOTRL/S,N,NOEED//
               NOUE $
 72  COND      ERROR2,NOEED $
 73  PARAM     //*MPY*/NEIGV/1/-1 $
 74  READ      KAA,MAA,MR,DM,EED,USET,CASECC/LAMA,PHIA,MI,OEIGS/*MODES*/  S,N,
               NEIGV $
 75  OFP       OEIGS,,,,,//S,N,CARDNO $
 76  COND      FINIS,NEIGV $
 77  OFP       LAMA,,,,,//S,N,CARDNO $
 78  SDR1      USET,,PHIA,,,GO,GM,,KFS,,/PHIG,,QG/1/*REIG* $
 79  COND      NOMPCF,GRDEQ $
 80  EQMCK     CASECC,EQEXIN,GPL,BGPDT,SIL,USET,KGG,GM,PHIG,LAMA,QG,CSTM/OQM1/
               V,Y,OPT=0/V,Y,GRDEQ/-1 $
 81  OFP       OQM1,,,,,//S,N,CARDNO $
 82  LABEL     NOMPCF $
 83  SDR2      CASECC,CSTM,MPT,DIT,EQEXIN,SIL,,,BGPDP,LAMA,QG,PHIG,EST,,/ ,
               OQG1,OPHIG,OES1,OEF1,PPHIG/*REIG* $
 84  OFP       OPHIG,OQG1,OEF1,OES1,,//S,N,CARDNO $
 85  COND      P2,JUMPPLOT $
 86  PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,,PPHIG,GPECT,OES1/
               PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $
 87  PRTMSG    PLOTX2// $
 88  LABEL     P2 $
 89  JUMP      FINIS $
 90  LABEL     ERROR1 $
 91  PRTPARM   //-1/*MODES* $
 92  LABEL     ERROR2 $
 93  PRTPARM   //-2/*MODES* $
 94  LABEL     ERROR3 $
 95  PRTPARM   //-3/*MODES* $
 96  LABEL     ERROR4 $
 97  PRTPARM   //-4/*MODES* $
 98  LABEL     FINIS $
 99  PURGE     DUMMY/ALWAYS $
100  END       $
```

3.4.2 Description of DMAP Operations for Normal Mode Analysis

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

7. GP2 generates Element Connection Table with internal indices.

10. Go to DMAP No. 18 if there are no structure plot requests.

11. PLTSET transforms user input into a form used to drive the structure plotter.

12. PRTMSG prints error messages associated with the structure plotter.

15. Go to DMAP No. 18 if no undeformed structure plots are requested.

16. PLØT generates all requested undeformed structure plots.

17. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

19. GP3 generates Grid Point Temperature Table.

20. TA1 generates element tables for use in matrix assembly and stress recovery.

21. Go to DMAP No. 96 and print Error Message No. 4 if there are no structural elements.

25. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

27. Go to DMAP No. 29 if no stiffness matrix is to be assembled.

28. EMA assembles stiffness matrix $[K^x_{gg}]$ and Grid Point Singularity Table.

30. Go to DMAP No. 90 and print Error Message No. 1 if no mass matrix is to be assembled.

31. EMA assembles mass matrix $[M_{gg}]$.

32. Go to DMAP No. 35 if no weight and balance information is requested.

33. GPWG generates weight and balance information.

34. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

36. Equivalence $[K^x_{gg}]$ to $[K_{gg}]$ if no general elements exist.

37. Go to DMAP No. 39 if no general elements exist.

38. SMA3 adds general elements to $[K^x_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

41. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations $[R_g]\{u_g\} = 0$.

42. Go to DMAP No. 94 and print Error Message No. 3 if no independent degrees of freedom are defined.

44. Go to DMAP No. 49 if general elements are present.

46. Go to DMAP No. 49 if no potential grid point singularities exist.

47. GPSP generates a table of potential grid point singularities.

48. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

50. Equivalence $[K_{gg}]$ to $[K_{nn}]$ and $[M_{gg}]$ to $[M_{nn}]$ if no multipoint constraints exist.

51. Go to DMAP No. 54 if no multipoint constraints exist.

52. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

53. MCE2 partitions stiffness and mass matrices

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right] \quad \text{and} \quad [M_{gg}] = \left[\begin{array}{c|c} \bar{M}_{nn} & M_{nm} \\ \hline M_{mn} & M_{mm} \end{array}\right]$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \quad \text{and}$$

$$[M_{nn}] = [\bar{M}_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m] \quad .$$

55. Equivalence $[K_{nn}]$ to $[K_{ff}]$ and $[M_{nn}]$ to $[M_{ff}]$ if no single-point constraints exist.

56. Go to DMAP No. 58 if no single-point constraints exist.

57. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right] \text{and} \quad [M_{nn}] = \left[\begin{array}{c|c} M_{ff} & M_{fs} \\ \hline M_{sf} & M_{ss} \end{array}\right] .$$

59. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

60. Equivalence $[M_{ff}]$ to $[M_{aa}]$ if no omitted coordinates exist.

61. Go to DMAP No. 64 if no omitted coordinates exist.

62. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right] ,$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

63. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \left[\begin{array}{c|c} \bar{M}_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right],$$

and performs matrix reduction

$$[M_{aa}] = [\bar{M}_{aa}] + [M_{oa}^T][G_o] + [G_o^T][M_{oa}] + [G_o^T][M_{oo}][G_o] \; .$$

65. Go to DMAP No. 70 if no free-body supports exist.

66. RBMG1 partitions out free-body supports

$$[K_{aa}] = \left[\begin{array}{c|c} K_{\ell\ell} & K_{\ell r} \\ \hline K_{r\ell} & K_{rr} \end{array}\right] \quad \text{and} \quad [M_{aa}] = \left[\begin{array}{c|c} M_{\ell\ell} & M_{\ell r} \\ \hline M_{r\ell} & M_{rr} \end{array}\right]$$

67. RBMG2 decomposes constrained stiffness matrix $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$.

68. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}],$$

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D]$$

and calculates rigid body error ratio

$$\varepsilon = \frac{||X||}{||K_{rr}||} \; .$$

69. RBMG4 forms rigid body mass matrix

$$[m_r] = [M_{rr}] + [M_{\ell r}^T][D] + [D^T][M_{\ell r}] + [D^T][M_{\ell\ell}][D].$$

71. DPD extracts Eigenvalue Extraction Data from Dynamics data block.

72. Go to DMAP No. 92 and print Error Message No. 2 if there is no Eigenvalue Extraction Data.

74. READ extracts real eigenvalues and eigenvectors from the equation

$$[K_{aa} - \lambda M_{aa}]\{u_a\} = 0 \quad ,$$

calculates rigid body modes by finding a square matrix $[\phi_{ro}]$ such that

$$[m_o] = [\phi_{ro}^T][m_r][\phi_{ro}]$$

is diagonal and normalized, computes rigid body eigenvectors

$$[\phi_{ao}] = \left[\begin{array}{c} D\phi_{ro} \\ \hline \phi_{ro} \end{array}\right] \; ,$$

calculates modal mass matrix

$$[m] = [\phi_a^T][M_{aa}][\phi_a]$$

and normalizes eigenvectors according to one of the following user requests:

1) Unit value of a selected component
2) Unit value of the largest component
3) Unit value of the generalized mass.

75. ØFP formats the summary of eigenvalue extraction information (ØEIGS) prepared by READ and places it on the system output file for printing.

76. Go to DMAP No. 98 and make normal exit if no eigenvalues were found.

77. ØFP formats the eigenvalues (LAMA) prepared by READ and places them on the system output file for printing.

78. SDR1 recovers dependent components of the eigenvectors

$$\{\phi_o\} = [G_o]\{\phi_a\} \quad , \qquad \left\{\begin{array}{c}\phi_a \\ \hline \phi_o\end{array}\right\} = \{\phi_f\} \quad ,$$

$$\left\{\begin{array}{c}\phi_f \\ \hline \phi_s\end{array}\right\} = \{\phi_n\} \quad , \qquad \{\phi_m\} = [G_m]\{\phi_n\} \quad ,$$

$$\left\{\begin{array}{c}\phi_n \\ \hline \phi_m\end{array}\right\} = \{\phi_g\}$$

and recovers single-point forces of constraint $\{q_s\} = [K_{fs}]^T\{\phi_f\}$.

79. Go to DMAP No. 82 if no multipoint constraint force balance is requested.

80. EQMCK calculates the force and moment equilibrium check and prepares the multipoint constraint force balance (ØQM1) for output.

81. ØFP formats the table prepared by EQMCK and places it on the system output file for printing.

83. SDR2 calculates element forces (ØEF1) and stresses (ØES1) and prepares eigenvectors (ØPHIG) and single-point forces of constraint (ØQG1) for output and translation components of the eigenvectors (PPHIG).

84. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

85. Go to DMAP No. 88 if no deformed structure plots are requested.

86. PLØT generates all requested deformed structure and contour plots.

87. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.

89. Go to DMAP No. 98 and make normal exit.

91. Print Error Message No. 1 and terminate execution.

93. Print Error Message No. 2 and terminate execution.

95. Print Error Message No. 3 and terminate execution.

97. Print Error Message No. 4 and terminate execution.

3.4.3 Output for Normal Mode Analysis

Earh eigenvalue is identified with a mode number determined by sorting the eigenvalues by their algebraic magnitude. The following summary of the eigenvalues extracted is automatically printed:

1. Mode Number
2. Extraction Order
3. Eigenvalue
4. Radian Frequency
5. Cyclic Frequency
6. Generalized Mass
7. Generalized Stiffness

The following summary of the eigenvalue analysis performed, using the Inverse Power method, is automatically printed:

1. Number of eigenvalues extracted.
2. Number of starting points used.
3. Number of starting point moves.
4. Number of triangular decompositions.
5. Number of vector iterations.
6. Reason for termination.
   (1) Two consecutive singularities encountered while performing triangular decomposition.
   (2) Four shift points while tracking a single root.
   (3) All eigenvalues found in the frequency range specified.
   (4) Three times the number of roots estimated in the frequency range have been extracted.
   (5) All eigenvalues that exist in the problem have been found.
   (6) The number of roots desired have been found.
   (7) One or more eigenvalues have been found outside the frequency range specified.
   (8) Insufficient time to find another root.
   (9) Unable to converge
7. Largest off-diagonal modal mass term and the number failing the criterion.

The following summary of the eigenvalue analysis performed, using the Determinant method, is automatically printed:

1. Number of eigenvalues extracted.
2. Number of passes through starting points.
3. Number of criteria changes.
4. Number of starting point moves.
5. Number of triangular decompositions.
6. Number of failures to iterate to a root.
7. Reason for termination.
   (1) The number of roots desired have been found.
   (2) All predictions for eigenvalues are outside the frequency range specified.
   (3) Insufficient time to find another root.
   (4) Matrix is singular at first three starting points.
8. Largest off-diagonal modal mass term and the number failing the criterion.
9. Swept determinant function for each starting point.

The following summary of the eigenvalue analysis performed, using the Givens method, is automatically printed:

1. Number of eigenvalues extracted.
2. Number of eigenvectors computed.
3. Number of eigenvalue convergence failures.
4. Number of eigenvector convergence failures.
5. Reason for termination.
   (1) Normal termination.
   (2) Insufficient time to calculate eigenvalues and number of eigenvectors requested.
   (3) Insufficient time to find additional eigenvectors.
6. Largest off-diagonal modal mass term and the number failing the criterion.

The following summary of the eigenvalue analysis performed, using the Tridiagonal Reduction (FEER - Fast Eigenvalue Extraction Routine) method, is automatically printed.

1. Number of eigenvalues extracted.
2. Number of starting points used.

   This corresponds to the total number of random starting and restart vectors used by the FEER process.

3. Number of starting point moves.

   Not used in FEER (set equal to zero).

4. Number of triangular decompositions.

   Always equal to one, except for unshifted vibration problems (roots starting from the lowest requested). In this case, a maximum of three shifts and three decompositions are employed to remove possible stiffness matrix singularities.

5. Total number of vector iterations.

   The total number of reorthogonalizations of all the trial vectors employed.

6. Reason for termination.

   (0) Normal termination.

   (1) Fewer than the requested number of eigenvalues and eigenvectors have been extracted.

   (3) The problem size has been reduced. However, the desired number of accurate eigensolutions specified on the EIGB or EIGR card may have been obtained. A detailed list of the computed error bounds can be obtained by requesting DIAG 16 in the Executive Control Deck.

7. Largest off-diagonal modal mass term and the number failing the mass orthogonality criterion.

The following output may be requested:

1. Eigenvectors along with the associated eigenvalue for each mode.
2. Nonzero components of the single-point forces of constraint for selected modes at selected grid points.
3. Forces and stresses in selected elements for selected modes.
4. Undeformed plot of the structural model and mode shapes for selected modes.
5. Contour plots of stresses and displacements for selected modes.

3.4.4 Case Control Deck for Normal Mode Analysis

The following items relate to subcase definition and data selection for Normal Mode Analysis:

1. METHØD must be used to select an EIGR card that exists in the Bulk Data Deck.
2. On restart, the current EIGR card controls the eigenvalue extraction, regardless of what calculations were made in the previous execution. Consequently, when making restarts

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with either the Determinant method, the Inverse Power method or the Tridiagonal Reduction (FEER) method, METHØD should be changed to select an EIGR card that avoids the extraction of previously found eigenvalues. This is particularly important following unscheduled exits due to insufficient time to find all eigenvalues in the range of interest.

3. An SPC set must be selected unless the model is a free body or all constraints are specified on GRID cards, Scalar Connection cards or with General Elements.
4. Multiple subcases are used only to control output requests. A single subcase is sufficient if the same output is desired for all modes. If multiple subcases are present, the output requests will be honored in succession for increasing mode numbers. MØDES may be used to repeat subcases in order to make the same output request for several consecutive modes.

3.4.5 Parameters for Normal Mode Analysis

The following parameters are used in Normal Mode Analysis:

1. GRDPNT - optional. A positive integer value of this parameter will cause the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
2. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in EMA. Not recommended for use in hydroelastic problems.
3. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters will cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. ØPT - optional. A positive integer value of this parameter causes both equilibrium and multipoint constraint forces to be calculated for the Case Control output request, MPCFØRCE. A negative integer value of this parameter causes only the equilibrium force balance to be calculated for the output request. The default value is 0 which causes only the multipoint constraint forces to be calculated for the output request.

5. GRDEQ - optional. A positive integer value of this parameter selects the grid point about which equilibrium will be checked for the Case Control output request, MPCFØRCE. If the integer value is zero, the basic origin is used. Default is -1.

6. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.

7. AUTØSPC - reserved for future optional use. The default value is -1.

3.4.6 Optional Diagnostic Output for FEER

Special detailed information related to the generation of the reduced problem size, the elements of the reduced tridiagonal matrix, computed error bounds and other numerical tests can be obtained by requesting DIAG 16 in the NASTRAN Executive Control Deck.

The meaning of this information is explained below in the order in which it appears in the DIAG 16 output.

ØRDER - The order of the unreduced problem (size of the $[K_{aa}]$ matrix)

MAX RANK - The maximum number of existing finite eigensolutions as initially detected by FEER

RED ØRDER - The order of the reduced eigenproblem which will be solved to obtain the number of accurate solutions requested by the user

ØRTH VCT - The number of previously computed accurate eigenvectors on the eigenvector file which were generated prior to a restart or by the NASTRAN rigid body mode generator

USER SHIFT - The user specified shift after conversion from cycles to radians - squared (used only in frequency problems).

INTERNAL SHIFT - A small positive value automatically computed to remove singularities if the user has specified a zero shift. Otherwise, the negative of the user shift (used only in frequency problems).

SINGULARITY CHECK - PASS: the shifted stiffness matrix is non-singular
- ****: the number of internal shifts needed to remove stiffness matrix singularities

TRIDIAGONAL ELEMENTS ROW j, **, ***, **** - The computed tridiagonal elements of the reduced eigenmatrix:
j - Matrix row
** - Diagonal element
*** - Off-diagonal element
**** - First estimate of off-diagonal element in the next row

ØRTH ITER - The number of times a reorthogonalization of a trial vector has been performed.

MAX PRØJ - The maximum projection of the above trial vector on the previously computed accurate trial vectors (prior to the current reorthogonalization)

NØRMAL FACT - The normalization factor for the reorthogonalized trial vector

ØPEN CØRE NØT USED *** FEER3 - Open core not used by Subroutine FEER3, in single-precision words

FEER QRW ELEMENT *, ITER **, ***, RATIØ ****, PRØJ *****:

* - The internal eigenvalue number in the order of its extraction by FEER

** - The number of inverse power iterations performed to extract the associated eigenvector of the reduced system (this is not a physical eigenvector)

*** - If a multiple root has been detected, the number of times that the previous multiple-root, reduced-system eigenvectors have been projected out of the current multiple-root eigenvector before repeating the inverse power iterations

**** - The absolute ratio of maximum, reduced-system eigenvector elements for successive inverse power iterations

***** - The maximum projection of a current multiple-root eigenvector on previously computed eigenvectors for the same root

PHYSICAL EIGENVALUE *, **, THEØR ERRØR *** PERCENT, PASS ØR FAIL:

* - The internal eigenvalue number in the order of its extraction by FEER

** - The associated physical eigenvalue (λ for buckling problems, ω^2 for frequency problems)

*** - Theoretical upper bound on the relative eigenvalue error

PASS - The computed error is less than or equal to the allowable specified on the EIGB or EIGR bulk data card (default is .001/n where n is the order of the stiffness matrix)

FAIL - The computed error is greater than the allowable and this mode is not accepted for further processing

ØPEN CØRE NØT USED *** FEER4 - Open core not used by Subroutine FEER4, in single-precision words

FEER CØMPLETE *, **, ***, ****

* - The remaining CPU time available following decomposition of the shifted stiffness matrix, in seconds (the total time is specified on the TIME card in the Executive Control Deck)

** - The remaining CPU time, in seconds after completing Subroutine FEER3

*** - The remaining CPU time, in seconds after completing Subroutine FEER4

**** - The total operation count for FEER after decomposition of the shifted stiffness matrix. One operation is considered to be a multiplication or division followed by an addition

3.4.7 The APPEND Feature

In real eigenvalue analysis, it is frequently necessary to add new eigenvalues and eigenvectors to those already computed in a previous run. The APPEND feature (see Section 9.2.2 of

the Theoretical Manual for details) makes it possible to do this without re-executing the entire problem. It is available when using the Inverse Power, Determinant and Tridiagonal Reduction (FEER) methods of eigenvalue extraction.

In order to use the APPEND feature, the user should employ the following steps:

1. Request a checkpoint of an eigenvalue problem by employing either the Inverse Power, Determinant or Tridiagonal Reduction (FEER) method.
2. Check to ensure that at least one eigenvalue and one eigenvector are computed in this run and that the LAMA (eigenvalue) and PHIA (eigenvector) files are successfully checkpointed.
3. Restart the problem by changing either the METHØD card in the Case Control Deck and/or the EIGR card in the Bulk Data Deck and ensuring that the following conditions are satisfied:
   a. The structural model and the constraint data for the restart <u>must</u> be the same as that used in the checkpoint run.
   b. The method of eigenvalue extraction employed in the restart <u>need not</u> be the same as that used in the checkpoint run, but the range of eigenvalues specified on the EIGR Bulk Data card <u>should not</u> include the eigenvalues already checkpointed in Step 1.
   c. If the user wishes to retrieve only a subset of the checkpointed eigenvalues and eigenvectors, a DMAP alter should be employed in the Executive Control Deck to reset the parameter NEIGV to the desired value by means of a PARAM statement just before the READ module in the DMAP sequence. (See Section 9.2.2 of the Theoretical Manual for details).
4. Note that the eigenvalues and eigenvectors output by the restart <u>include</u> those retrieved from the checkpointed run of Step 1. Also, the resulting eigenvectors are normalized according to the method of normalization specified in the restart.

3.4.8 <u>Automatic ALTERs for Automated Multi-stage Substructuring</u>

The following lines of the Normal Mode Analysis, Rigid Format 3, are ALTERed in automated substructure analyses.

Phase 1: 4, 42, 65-70, 71-89

Phase 2: 4, 5-5, 8-18, 21-21, 30-30, 36-39, 44-49, 79-91

Phase 3: 65-70, 71-77, 78

If APP DISP, SUBS is used, the user may also specify ALTERs. However, these must not interfere with the automatically generated DMAP statement ALTERs listed above. See Section 5.9 for a description and listing of the ALTERs which are automatically generated for substructuring.

3.4.9 Rigid Format Error Messages from Normal Mode Analysis

The following fatal errors are detected by the DMAP statements in the Normal Mode Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

NØRMAL MØDE ANALYSIS ERRØR MESSAGE NØ. 1 - MASS MATRIX REQUIRED FØR REAL EIGENVALUE ANALYSIS.

The mass matrix is null because either no structural elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

NØRMAL MØDE ANALYSIS ERRØR MESSAGE NØ. 2 - EIGENVALUE EXTRACTIØN DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGR card in the Bulk Data Deck and METHØD in the Case Control Deck must select an EIGR set.

NØRMAL MØDE ANALYSIS ERRØR MESSAGE NØ. 3 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, SUPØRT, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

NØRMAL MØDE ANALYSIS ERRØR MESSAGE NØ. 4 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

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3.5 STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS

3.5.1 DMAP Sequence for Static Analysis with Differential Stiffness

```
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DISPLACEMENT APPROACH, RIGID FORMAT 4

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

OPTIONS IN EFFECT   GO      ERR=2   LIST    NODECK  NOREF   NOOSCAR

   1  BEGIN    DISP 04 - DIFFERENTIAL STIFFNESS ANALYSIS - APR. 1984 $
   2  PRECHK   ALL $
   3  PARAM    //*MPY*/CARDNO/0/0 $
   4  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  S,N,
               NOGPDT/MINUS1=-1 $
   5  COND     ERROR3,NOGPDT $
   6  PLTTRAN  BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $
   7  GP2      GEOM2,EQEXIN/ECT $
   8  PARAML   PCDB//*PRES*////JUMPPLOT $
   9  PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $
  10  COND     P1,JUMPPLOT $
  11  PLTSET   PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/   S,N,
               JUMPPLOT $
  12  PRTMSG   PLTSETX// $
  13  PARAM    //*MPY*/PLTFLG/1/1 $
  14  PARAM    //*MPY*/PFILE/0/0 $
  15  COND     P1,JUMPPLOT $
  16  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
               NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $
  17  PRTMSG   PLOTX1// $
  18  LABEL    P1 $
  19  GP3      GEOM3,EQEXIN,GEOM2/SLT,GPTT/S,N,NOGRAV $
  20  PARAM    //*AND*/NOMGG/NOGRAV/V,Y,GRDPNT=-1 $
  21  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/LUSET/S,N,NOSIMP/1/
               S,N,NOGENL/S,N,GENEL $
  22  COND     ERROR1,NOSIMP $
  23  PURGE    OGPST/GENEL $
  24  PARAM    //*ADD*/NOKGGX/1/0 $
  25  EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,/S,N,NOKGGX/ S,
               N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/C,Y,CPQUAD1/C,Y,
               CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/  C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,
               CPTRPLT/C,Y,CPTRBSC $
  26  PURGE    KGGX,GPST/NOKGGX/MGG/NOMGG $
  27  COND     JMPKGG,NOKGGX $
  28  EMA      GPECT,KDICT,KELM/KGGX,GPST $
  29  LABEL    JMPKGG $
```

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DISPLACEMENT APPROACH, RIGID FORMAT 4

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
30 COND     JMPMGG,NOMGG $
31 EMA      GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $
32 LABEL    JMPMGG $
33 COND     LBL1,GRDPNT $
34 COND     ERROR4,NOMGG $
35 GPWG     BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT/C,Y,WTMASS $
36 OFP      OGPWG,,,,,//S,N,CARDNO $
37 LABEL    LBL1 $
38 EQUIV    KGGX,KGG/NOGENL $
39 COND     LBL11,NOGENL $
40 SMA3     GE1,KGGX/KGG/LUSET/NOGENL/NOSIMP $
41 LABEL    LBL11 $
42 PARAM    //*MPY*/NSKIP/0/0 $
43 CASE     CASECC,/CASEXX/*TRANRESP*/0/NOLOOP $
44 GP4      CASEXX,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,YS,USET,ASET/
            LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/S,N,
            NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/ S,Y,
            AUTOSPC $
45 COND     ERROR5,NOL $
46 PURGE    GM/MPCF1/GO,KOO,LOO,PO,UOOV,RUOV/OMIT/PS,KFS,KSS,QG,   YBS,PBS,
            KBFS,KBSS,KDFS,KDSS/SINGLE $
47 COND     LBL4D,REACT $
48 JUMP     ERROR2 $
49 LABEL    LBL4D $
50 COND     LBL4,GENEL$
51 PARAM    //*EQ*/GPSPFLG/AUTOSPC/0 $
52 COND     LBL4,GPSPFLG $
53 GPSP     GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
54 OFP      OGPST,,,,,//S,N,CARDNO $
55 LABEL    LBL4 $
56 EQUIV    KGG,KNN/MPCF1 $
57 COND     LBL2,MPCF1 $
58 MCE1     USET,RG/GM $
59 MCE2     USET,GM,KGG,,,/KNN,,, $
60 LABEL    LBL2 $
61 EQUIV    KNN,KFF/SINGLE $
62 COND     LBL3,SINGLE $
63 SCE1     USET,KNN,,,/KFF,KFS,KSS,,, $
64 LABEL    LBL3 $
```

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DISPLACEMENT APPROACH, RIGID FORMAT 4

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
65  EQUIV   KFF,KAA/OMIT $
66  COND    LBL5,OMIT $
67  SMP1    USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
68  LABEL   LBL5 $
69  RBMG2   KAA/LLL $
70  SSG1    SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,CASEXX,DIT,/PG,,,,/
            LUSET/1 $
71  EQUIV   PG,PL/NOSET $
72  COND    LBL10,NOSET $
73  SSG2    USET,GM,YS,KFS,GO,,PG/,PO,PS,PL $
74  LABEL   LBL10 $
75  SSG3    LLL,KAA,PL,LOO,KOO,PO/ULV,UOOV,RULV,RUOV/OMIT/V,Y,IRES=-1/ 1/S,
            N,EPSI $
76  COND    LBL9,IRES $
77  MATGPR  GPL,USET,SIL,RULV//*L* $
78  MATGPR  GPL,USET,SIL,RUOV//*O* $
79  LABEL   LBL9 $
80  SDR1    USET,,ULV,UOOV,YS,GO,GM,PS,KFS,KSS,/UGV,PG1,QG/1/*DS0* $
81  SDR2    CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QG,UGV,EST,,PG/
            OPG1,OQG1,OUGV1,OES1,OEF1,PUGV1/*DS0* $
82  OFP     OUGV1,OPG1,OQG1,OEF1,OES1,//S,N,CARDNO $
83  COND    P2,JUMPPLOT $
84  PLOT    PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUGV1,,GPECT,OES1/
            PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $
85  PRTMSG  PLOTX2// $
86  LABEL   P2 $
87  TA1     ECT,EPT,BGPDT,SIL,GPTT,CSTM/X1,X2,X3,ECPT,GPCT/LUSET/   NOSIMP/
            0/NOGENL/GENEL $
88  DSMG1   CASECC,GPTT,SIL,EDT,UGV,CSTM,MPT,ECPT,GPCT,DIT/KDGG/  DSCOSET $
89  PARAM   //*ADD*/SHIFT/-1/0 $
90  PARAM   //*ADD*/COUNT/ALWAYS=-1/NEVER= 1 $
91  PARAMR  //*ADD*/DSEPSI/0.0/0.0 $
92  PARAML  YS//*NULL*////NOYS $
93  LABEL   OUTLPTOP $          Top of Stiffness Adjustment Loop
94  EQUIV   PG,PG1/NOYS $
95  PARAM   //*KLOCK*/TO $
96  EQUIV   KDGG,KDNN/MPCF1 $
97  COND    LBL2D,MPCF1 $
98  MCE2    USET,GM,KDGG,,,/KDNN,,, $
99  LABEL   LBL2D $
```

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DISPLACEMENT APPROACH, RIGID FORMAT 4

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
100  EQUIV    KDNN,KDFF/SINGLE $
101  COND     LBL3D,SINGLE $
102  SCE1     USET,KDNN,,,/KDFF,KDFS,KDSS,,, $
103  LABEL    LBL3D $
104  EQUIV    KDFF,KDAA/OMIT $
105  COND     LBL5D,OMIT $
106  SMP2     USET,GO,KDFF/KDAA $
107  LABEL    LBL5D $
108  ADD      KAA,KDAA/KBLL $
109  ADD      KFS,KDFS/KBFS $
110  ADD      KSS,KDSS/KBSS $
111  COND     PGOK,NOYS $
112  MPYAD    KBSS,YS,/PSS/0/1/1/1 $
113  MPYAD    KBFS,YS,/PFS/0/1/1/1 $
114  UMERGE   USET,PFS,PSS/PN/*N*/*F*/*S* $
115  EQUIV    PN,PGX/MPCF1 $
116  COND     LBL6D,MPCF1 $
117  UMERGE   USET,PN,/PGX/*G*/*N*/*M* $
118  LABEL    LBL6D $
119  ADD      PGX,PG/PGG/(-1.0,0.0) $
120  EQUIV    PGG,PG1/ALWAYS $
121  LABEL    PGOK $
122  ADD      PG1,/PG0/ $
123  RBMG2    KBLL/LBLL/S,N,POWER/S,N,DET $
124  PRTPARM  //0/*DET* $
125  PRTPARM  //0/*POWER* $
126  LABEL    INLPTOP $                          Top of Load Correction Loop
127  PARAM    //*KLOCK*/TI $
128  SSG2     USET,GM,YS,KDFS,GO,,PG1/,PBO,PBS,PBL $
129  SSG3     LBLL,KBLL,PBL,,,/UBLV,,RUBLV,/-1/V,Y,IRES/NDSKIP/S,N,  EPSI $
130  COND     LBL9D,IRES $
131  MATGPR   GPL,USET,SIL,RUBLV//*L* $
132  LABEL    LBL9D $
133  SDR1     USET,,UBLV,,YS,GO,GM,PBS,KBFS,KBSS,/UBGV,,QBG/1/*BS1* $
134  ADD      UBGV,UGV/DUGV/(-1.0,0.0) $
135  DSMG1    CASECC,GPTT,SIL,EDT,DUGV,CSTM,MPT,ECPT,GPCT,DIT/DKDGG/DSCOSET $
136  MPYAD    DKDGG,UBGV,PG0/PGI1/0/1/1/0 $
```


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     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

137  DSCHK     PG1,PGI1,UBGV//C,Y,EPSIO=1.E-5/S,N,DSEPSI/C,Y,NT=10/TO/    TI/S,
               N,DONE/S,N,SHIFT/S,N,COUNT/C,Y,BETAD=4 $
138  COND      DONE,DONE $
139  COND      SHIFT,SHIFT $
140  EQUIV     PG,PG1/NEVER/PGI1,PG1/ALWAYS/PG1,PGI1/NEVER $
141  REPT      INLPTOP,1000 $
                                          Bottom of Load Correction Loop
142  TABPT     PGI1,PG1,PG,,// $
143  LABEL     SHIFT $
144  ADD       DKDGG,KDGG/KDGG1/(-1.0,0.0) $
145  EQUIV     UBGV,UGV/ALWAYS/KDGG1,KDGG/ALWAYS $
146  EQUIV     KDGG,KDGG1/NEVER/UGV,UBGV/NEVER $
147  REPT      OUTLPTOP,1000 $
                                          Bottom of Stiffness Adjustment Loop
148  TABPT     KDGG1,KDGG,UGV,,// $
149  LABEL     DONE $
150  SDR2      CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QBG,UBGV,EST,,/
               ,OQBG1,OUBGV1,OESB1,OEFB1,PUBGV1/*DS1* $
151  OFP       OUBGV1,OQBG1,OEFB1,OESB1,,//S,N,CARDNO $
152  COND      P3,JUMPPLOT $
153  PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUBGV1,,GPECT,
               OESB1/PLOTX3/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $
154  PRTMSG    PLOTX3// $
155  LABEL     P3 $
156  JUMP      FINIS $
157  LABEL     ERROR1 $
158  PRTPARM   //-1/*DIFFSTIF* $
159  LABEL     ERROR2 $
160  PRTPARM   //-2/*DIFFSTIF* $
161  LABEL     ERROR3 $
162  PRTPARM   //-3/*DIFFSTIF* $
163  LABEL     ERROR4 $
164  PRTPARM   //-4/*DIFFSTIF* $
165  LABEL     ERROR5 $
166  PRTPARM   //-5/*DIFFSTIF* $
167  LABEL     FINIS $
168  PURGE     DUMMY/MINUS1 $
169  END       $
```

3.5.2 Description of DMAP Operations for Static Analysis with Differential Stiffness

4. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

5. Go to DMAP No. 161 and print Error Message No. 3 if there is no Grid Point Definition Table.

6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

7. GP2 generates Element Connection Table with internal indices.

10. Go to DMAP No. 18 if there are no structure plot requests.

11. PLTSET transforms user input into a form used to drive the structure plotter.

12. PRTMSG prints error messages associated with the structure plotter.

15. Go to DMAP No. 18 if no undeformed structure plots are requested.

16. PLØT generates all requested undeformed structure plots.

17. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

19. GP3 generates Static Loads Table and Grid Point Temperature Table.

21. TA1 generates element tables for use in matrix assembly and stress recovery.

22. Go to DMAP No. 157 and print Error Message No. 1 if there are no structural elements.

25. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

27. Go to DMAP No. 29 if no stiffness matrix is to be assembled.

28. EMA assembles stiffness matrix $[K_{gg}^x]$ and Grid Point Singularity Table.

30. Go to DMAP No. 32 if no mass matrix is to be assembled.

31. EMA assembles mass matrix $[M_{gg}]$.

33. Go to DMAP No. 37 if no weight and balance information is requested.

34. Go to DMAP No. 163 and print Error Message No. 4 if no mass matrix exists.

35. GPWG generates weight and balance information.

36. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

38. Equivalence $[K_{gg}^x]$ to $[K_{gg}]$ if no general elements exist.

39. Go to DMAP No. 41 if no general elements exist.

40. SMA3 adds general elements to $[K_{gg}^x]$ to obtain stiffness matrix $[K_{gg}]$.

43. CASE copies the first record of CASECC to CASEXX.

44. GP4 generates flags defining members of various displacement sets (USET), forms multipoint constraint equations $[R_g]\{u_g\} = 0$ and forms enforced displacement vector $\{Y_s\}$.

45. Go to DMAP No. 165 and print Error Message No. 5 if no independent degrees of freedom are defined.

47. Go to DMAP No. 49 if no free-body supports are supplied.

48. Go to DMAP No. 159 and print Error Message No. 2.

50. Go to DMAP No. 55 if general elements are present.

52. Go to DMAP No. 55 if no potential grid point singularities exist.

53. GPSP generates a table of potential grid point singularities.

54. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

56. Equivalence $[K_{gg}]$ to $[K_{nn}]$ if no multipoint constraints exist.

57. Go to DMAP No. 60 if no multipoint constraints exist.

58. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

59. MCE2 partitions stiffness matrix

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right]$$

and performs matrix reduction

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m].$$

61. Equivalence $[K_{nn}]$ to $[K_{ff}]$ if no single-point constraints exist.

62. Go to DMAP No. 64 if no single-point constraints exist.

63. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right].$$

65. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

66. Go to DMAP No. 68 if no omitted coordinates exist.

67. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right],$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

69. RMBG2 decomposes constrained stiffness matrix $[K_{aa}] = [L_{\ell\ell}][U_{\ell\ell}]$.

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70. SSG1 generates static load vectors $\{P_g\}$.

71. Equivalence $\{P_g\}$ to $\{P_\ell\}$ if no constraints are applied.

72. Go to DMAP No. 74 if no constraints are applied.

73. SSG2 applies constraints to static load vectors

$$\{P_g\} = \left\{\frac{\bar{P}_n}{P_m}\right\} , \qquad \{P_n\} = \{\bar{P}_n\} + [G_m^T]\{P_m\} ,$$

$$\{P_n\} = \left\{\frac{\bar{P}_f}{P_s}\right\} , \qquad \{P_f\} = \{\bar{P}_f\} - [K_{fs}]\{Y_s\} ,$$

$$\{P_f\} = \left\{\frac{P_a}{P_o}\right\} \quad \text{and} \quad \{P_\ell\} = \{P_a\} + [G_o^T]\{P_o\} .$$

75. SSG3 solves for displacements of independent coordinates

$$\{u_\ell\} = [K_{aa}]^{-1}\{P_\ell\} ,$$

solves for displacements of omitted coordinates

$$\{u_o^o\} = [K_{oo}]^{-1}\{P_o\} ,$$

calculates residual vector (RULV) and residual vector error ratio for independent coordinates

$$\{\delta P_\ell\} = \{P_\ell\} - [K_{aa}]\{u_\ell\} ,$$

$$\varepsilon_\ell = \frac{\{u_\ell^T\}\{\delta P_\ell\}}{\{P_\ell^T\}\{u_\ell\}}$$

and calculates residual vector (RUØV) and residual vector error ratio for omitted coordinates

$$\{\delta P_o\} = \{P_o\} - [K_{oo}]\{u_o^o\} ,$$

$$\varepsilon_o = \frac{\{u_o^T\}\{\delta P_o\}}{\{P_o^T\}\{u_o^o\}} .$$

76. Go to DMAP No. 79 if residual vectors are not to be printed.

77. MATGPR prints the residual vector for independent coordinates (RULV).

78. MATGPR prints the residual vector for omitted coordinates (RUØV).

80. SDR1 recovers dependent displacements

$$\{u_o\} = [G_o]\{u_\ell\} + \{u_o^o\} \quad ,$$

$$\left\{\frac{u_a}{u_o}\right\} = \{u_f\} \quad , \qquad \left\{\frac{u_f}{Y_s}\right\} = \{u_n\} \quad ,$$

$$\{u_m\} = [G_m]\{u_n\} \quad , \qquad \left\{\frac{u_n}{u_m}\right\} = \{u_g\}$$

and recovers single-point forces of constraint

$$\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\} + [K_{ss}]\{Y_s\}.$$

81. SDR2 calculates element forces (ØEF1) and stresses (ØES1) and prepares load vectors (ØPG1), displacement vectors (ØUGV1) and single-point forces of constraint (ØQG1) for output and translation components of the displacement vector (PUGV1) for the static solution.

82. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

83. Go to DMAP No. 86 if no deformed static solution structure plots are requested.

84. PLØT generates all requested static solution deformed structure and contour plots.

85. PRTMSG prints plotter data, engineering data, and contour data for each deformed static solution plot generated.

87. TA1 generates element tables for use in differential stiffness matrix assembly.

88. DSMG1 generates differential stiffness matrix $[K_{gg}^d]$.

93. Beginning of outer (stiffness adjustment) loop for differential stiffness iteration.

94. Equivalence $\{P_g\}$ to $\{P_{g1}\}$ if no enforced displacements are specified.

96. Equivalence $[K_{gg}^d]$ to $[K_{nn}^d]$ if no multipoint constraints exist.

97. Go to DMAP No. 99 if no multipoint constraints exist.

98. MCE2 partitions differential stiffness matrix

$$[K_{gg}^d] = \left[\begin{array}{c|c} \bar{K}_{nn}^d & K_{nm}^d \\ \hline K_{mn}^d & K_{mm}^d \end{array}\right]$$

and performs matrix reduction

$$[K_{nn}^d] = [\bar{K}_{nn}^d] + [G_m^T][K_{mn}^d] + [K_{mn}^d][G_m] + [G_m^T][K_{mm}^d][G_m].$$

100. Equivalence $[K_{nn}^d]$ to $[K_{ff}^d]$ if no single-point constraints exist.

101. Go to DMAP No. 103 if no single-point constraints exist.

102. SCE1 partitions out single-point constraints

$$[K^d_{nn}] = \left[\begin{array}{c|c} K^d_{ff} & K^d_{fs} \\ \hline K^d_{sf} & K^d_{ss} \end{array}\right].$$

104. Equivalence $[K^d_{ff}]$ to $[K^d_{aa}]$ if no omitted coordinates exist.

105. Go to DMAP No. 107 if no omitted coordinates exist.

106. SMP2 partitions constrained differential stiffness matrix

$$[K^d_{ff}] = \left[\begin{array}{c|c} \bar{K}^d_{aa} & K^d_{ao} \\ \hline K^d_{oa} & K^d_{oo} \end{array}\right].$$

and performs matrix reduction

$$[K^d_{aa}] = [\bar{K}^d_{aa}] + [K^d_{oa}]^T[G_o] + [G_o]^T[K^d_{oa}] + [G_o]^T[K^d_{oo}][G_o].$$

108. ADD $[K_{aa}]$ and $[K^d_{aa}]$ to form $[K^b_{\ell\ell}]$.

109. ADD $[K_{fs}]$ and $[K^d_{fs}]$ to form $[K^b_{fs}]$.

110. ADD $[K_{ss}]$ and $[K^d_{ss}]$ to form $[K^b_{ss}]$.

111. Go to DMAP No. 121 if no enforced displacements are specified.

112. MPYAD multiplies $[K^b_{ss}]$ and $\{Y_s\}$ to form $\{P_{ss}\}$.

113. MYPAD multiplies $[K^b_{fs}]$ and $\{Y_s\}$ to form $\{P_{fs}\}$.

114. UMERGE combines $\{P_{fs}\}$ and $\{P_{ss}\}$ to form $\{P_n\}$.

115. Equivalence $\{P_n\}$ to $\{P^x_g\}$ if no multipoint constraints exist.

116. Go to DMAP No. 118 if no multipoint constraints exist.

117. UMERGE expands $\{P_n\}$ to form $\{P^x_g\}$.

119. ADD $-\{P^x_g\}$ and $\{P_g\}$ to form $\{P_{gg}\}$.

120. Equivalence $\{P_{gg}\}$ to $\{P_{g1}\}$.

122. ADD $\{P_{g1}\}$ and nothing to create $\{P_{go}\}$.

123. RBMG2 decomposes the combined differential stiffness matrix and elastic stiffness matrix

$$[K^b_{\ell\ell}] = [L^b_{\ell\ell}][U^b_{\ell\ell}].$$

124. PRTPARM prints the scaled value of the determinant of the combined differential stiffness matrix and elastic stiffness matrix.

125. PRTPARM prints the scale factor (power of ten) of the determinant of the combined differential stiffness matrix and elastic stiffness matrix.

126. Beginning of inner (load correction) loop for differential stiffness iteration.

128. SSG2 applies constraints to static load vectors

$$\{P_{g1}\} = \left\{\begin{array}{c} \bar{P}^b_n \\ \hline P^b_m \end{array}\right\} , \qquad \{P^b_n\} = \{\bar{P}^b_n\} + [G^T_m]\{P^b_m\} ,$$

$$\{P^b_n\} = \left\{\begin{array}{c} \bar{P}^b_f \\ \hline P^b_s \end{array}\right\} , \qquad \{P_f\} = \{\bar{P}^b_f\} - [K^d_{fs}]\{Y_s\} ,$$

$$\{P^b_f\} = \left\{\begin{array}{c} \bar{P}^b_a \\ \hline P^b_o \end{array}\right\} \quad \text{and} \quad \{P^b_\ell\} = \{P^b_a\} + [G^T_o]\{P^b_o\} .$$

129. SSG3 solves for displacements of independent coordinates for current differential stiffness load vector

$$\{u^b_\ell\} = [K^b_{\ell\ell}]^{-1}\{P^b_\ell\} ,$$

and calculates residual vector (RBULV) and residual vector error ratio for current differential stiffness load vector

$$\{\delta P^b_\ell\} = \{P^b_\ell\} - [K^b_{\ell\ell}]\{u^b_\ell\} ,$$

$$\varepsilon^b_\ell = \frac{\{u^b_\ell\}^T\{\delta P^b_\ell\}}{\{P^b_\ell\}^T\{u^b_\ell\}}$$

130. Go to DMAP No. 132 if the residual vector for current differential stiffness solution is not to be printed.

131. MATGPR prints the residual vector for current differential stiffness solution.

133. SDR1 recovers dependent displacements for the current differential stiffness solution

$$\{u^b_o\} = [G_o]\{u^b_\ell\} + \{u^{ob}_o\} , \qquad \left\{\begin{array}{c} u^b_\ell \\ \hline u^b_o \end{array}\right\} = \{u_f\} ,$$

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$$\left\{\begin{array}{c} u_f^b \\ \hline Y_s^b \end{array}\right\} = \{u_n^b\} \quad , \qquad \{u_m^b\} = [G_m]\{u_n^b\} \quad ,$$

$$\left\{\begin{array}{c} u_n^b \\ \hline u_m^b \end{array}\right\} = \{u_g^b\}$$

and recovers single-point forces of constraint for the current differential stiffness solution

$$\{q_s^b\} = -\{P_s^b\} + [K_{sf}^b]\{u_f^b\} + [K_{ff}^b]\{Y_s^b\} \ .$$

134. ADD $-\{U_g^b\}$ and $\{U_g\}$ to form $\{U_g^d\}$.

135. DSMG1 generates differential stiffness matrix $[\delta K_{gg}^d]$

136. MYPAD forms the load vector for inner loop iteration

$$\{P_{g_{I1}}\} = [\delta K_{gg}^d]\{U_g^b\} + \{P_{go}\}$$

137. DSCHK performs differential stiffness convergence checks.

138. Go to DMAP No. 149 if differential stiffness iteration is complete.

139. Go to DMAP No. 143 if additional differential stiffness matrix changes are necessary for further iteration.

140. Break the previous equivalence of $\{P_g\}$ to $\{P_{g1}\}$ and $\{P_{g1}\}$ to $\{P_{g_{I1}}\}$ and establish equivalence of $\{P_{g_{I1}}\}$ to $\{P_{g1}\}$.

141. Go to DMAP No. 126 for an additional inner loop differential stiffness iteration.

142. TABPT table prints vectors $\{P_{g_{I1}}\}$, $\{P_{g1}\}$, and $\{P_g\}$.

144. ADD $-[\delta K_{gg}^d]$ and $[K_{gg}^d]$ to form $[K_{gg1}^d]$.

145. Equivalence $\{U_g^b\}$ to $\{U_g\}$ and $[K_{gg1}^d]$ to $[K_{gg}^d]$.

146. Break the previous equivalence of $[K_{gg}^d]$ to $[K_{gg1}^d]$ and $\{U_g\}$ to $\{U_g^b\}$.

147. Go to DMAP No. 93 for an additional outer loop differential stiffness iteration.

148. TABPT table prints $[K_{gg1}^d]$, $[K_{gg}^d]$, and $\{U_g\}$.

150. SDR2 calculates element forces (ØEFB1) and stresses (ØESB1) and prepares displacement vectors (ØUBGV1) and single-point forces of constraint (ØQBG1) for output and translation components of the displacement vector (PUBGV1) for the differential stiffness solution.

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STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS

151. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

152. Go to DMAP No. 155 if no differential stiffness solution deformed plots are requested.

153. PLØT generates all requested differential stiffness solution deformed structure and contour plots.

154. PRTMSG prints plotter data, engineering data, and contour data for each differential stiffness solution deformed plot generated.

156. Go to DMAP No. 167 and make normal exit.

158. Print Error Message No. 1 and terminate execution.

160. Print Error Message No. 2 and terminate execution.

162. Print Error Message No. 3 and terminate execution.

164. Print Error Message No. 4 and terminate execution.

166. Print Error Message No. 5 and terminate execution.

3.5.3 Output for Static Analysis with Differential Stiffness

The value of the determinant of the sum of the elastic stiffness and the differential stiffness is automatically printed for each differential stiffness loading condition.

Iterative differential stiffness computations are terminated for one of five reasons. Iteration termination reasons are automatically printed in an information message. These reasons have the following meanings:

1. REASON 0 means the iteration procedure was incomplete at the time of exit. This is caused by either an unexpected interruption of the iteration procedure (i.e., system abort) or termination is not scheduled (for the other four reasons) at the completion of the current iteration.
2. REASON 1 means the iteration procedure converged to the EPSIØ value supplied by the user on a PARAM bulk data card. (The default value of EPSIØ is 1.0E-5.)
3. REASON 2 means the iteration procedure is diverging from the EPSIØ value supplied by the user on a PARAM bulk data card. (The default value of EPSIØ is 1.0E-5.)
4. REASON 3 means insufficient time remaining to achieve convergence to the EPSIØ value supplied by the user on a PARAM bulk data card. (The default value of EPSIØ is 1.0E-5.)
5. REASON 4 means the number of iterations supplied by the user on a PARAM bulk data card has been met. (The default number of iterations is 10.)

Parameter values at the time of exit are automatically output as follows:

1. Parameter DØNE: -1 is normal; + N is the estimate of the number of iterations required to achieve convergence.
2. Parameter SHIFT: +1 indicates a return to the top of the inner loop was scheduled; -1 indicates a return to top of the outer loop was scheduled following the current iteration.
3. Parameter DSEPSI: the value of the ratio of energy error to total energy at the time of exit.

The following output may be requested:

1. Nonzero Components of the applied static load for the linear solution at selected grid points.
2. Displacements and nonzero components of the single-point forces of constraint, with and without differential stiffness, at selected grid points.
3. Forces and stresses in selected elements, with and without differential stiffness.

4. Undeformed and deformed plots of the structural model.
5. Contour plots of stresss and displacements.

3.5.4 Case Control Deck for Static Analysis with Differential Stiffness

The following items relate to subcase definition and data selection for Static Analysis with Differential Stiffness:

1. The Case Control Deck must contain two subcases.
2. A static loading condition must be defined above the subcase level with a LØAD, TEMPERATURE (LØAD), or DEFØRM selection, unless all loading is specified by grid point displacements on SPC cards.
3. An SPC set must be selected above the subcase level unless all constraints are specified on GRID cards.
4. Output requests that apply only to the linear solution must appear in the first subcase.
5. Output requests that apply only to the solution with differential stiffness must be placed in the second subcase.
6. Output requests that apply to both solutions, with and without differential stiffness, may be placed above the subcase level.

3.5.5 Parameters for Static Analysis with Differential Stiffness

The following parameters are used in Static Analysis with Differential Stiffness:

1. GRDPNT - optional. A positive integer value of this parameter will cause the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed.
2. WTMASS - optional. The terms of the mass matrix are multiplied by the real value of this parameter when they are generated in EMA.
3. IRES - optional. A positive integer value of this parameter will cause the printing of the residual vectors following the execution of SSG3.
4. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters will cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.

5. BETAD - optional. The integer value of this parameter is the assumed number of iterations for the inner loop in shift decisions for iterated differential stiffness. The default value is 4 iterations.

6. NT - optional. The integer value of this parameter limits the maximum number of iterations. The default value is 10 iterations.

7. EPSIØ - optional. The real value of this parameter is used to test the convergence of iterated differential stiffness. The default value is 10^{-5}.

8. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.

9. AUTØSPC - reserved for future optional use. The default value is -1.

3.5.6 Rigid Format Error Messages from Static Analysis with Differential Stiffness

The following fatal errors are detected by the DMAP statements in the Static Analysis with Differential Stiffness rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 1 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 2 - FREE BØDY SUPPØRTS NØT ALLØWED.

Free bodies are not allowed in Static Analysis with Differential Stiffness. The SUPØRT cards must be removed from the Bulk Data Deck and other constraints applied if required for stability.

STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 3 - NØ GRID PØINT DATA IS SPECIFIED.

No points have been defined with GRID or SPØINT cards.

STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 4 - MASS MATRIX REQUIRED FØR WEIGHT AND BALANCE CALCULATIØNS.

The mass matrix is null because either no elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 5 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

3.6 BUCKLING ANALYSIS

3.6.1 DMAP Sequence for Buckling Analysis

RIGID FORMAT DMAP LISTING
RELEASE APR. 1984

DISPLACEMENT APPROACH, RIGID FORMAT 5

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
OPTIONS IN EFFECT   GO    ERR=2   LIST   NODECK  NOREF   NOOSCAR

  1  BEGIN     DISP 05 - BUCKLING ANALYSIS - APR. 1984 $
  2  PRECHK    ALL $
  3  FILE      LAMA=APPEND/PHIA=APPEND $
  4  PARAM     //*MPY*/CARDNO/0/0 $
  5  GP1       GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  NOGPDT/
               MINUS1=-1 $
  6  PLTTRAN   BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $
  7  GP2       GEOM2,EQEXIN/ECT $
  8  PARAML    PCDB//*PRES*////JUMPPLOT $
  9  PURGE     PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $
 10  COND      P1,JUMPPLOT $
 11  PLTSET    PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/   S,N,
               JUMPPLOT $
 12  PRTMSG    PLTSETX// $
 13  PARAM     //*MPY*/PLTFLG/1/1 $
 14  PARAM     //*MPY*/PFILE/0/0 $
 15  COND      P1,JUMPPLOT $
 16  PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
               NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $
 17  PRTMSG    PLOTX1// $
 18  LABEL     P1 $
 19  GP3       GEOM3,EQEXIN,GEOM2/SLT,GPTT/S,N,NOGRAV $
 20  PARAM     //*AND*/NOMGG/NOGRAV/V,Y,GRDPNT=-1 $
 21  TA1       ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/LUSET/S,N,NOSIMP/1/
               S,N,NOGENL/S,N,GENEL $
 22  COND      ERROR1,NOSIMP $
 23  PURGE     OGPST/GENEL $
 24  PARAM     //*ADD*/NOKGGX/1/0 $
 25  EMG       EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,/S,N,NOKGGX/ S,
               N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/C,Y,CPQUAD1/C,Y,
               CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/  C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,
               CPTRPLT/C,Y,CPTRBSC $
 26  PURGE     KGGX,GPST/NOKGGX/MGG/NOMGG $
 27  COND      JMPKGG,NOKGGX $
 28  EMA       GPECT,KDICT,KELM/KGGX,GPST $
 29  LABEL     JMPKGG $
```

RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 5

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
30 COND    JMPMGG,NOMGG $
31 EMA     GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $
32 LABEL   JMPMGG $
33 COND    LBL1,GRDPNT $
34 COND    ERROR5,NOMGG $
35 GPWG    BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT/C,Y,WTMASS $
36 OFP     OGPWG,,,,,//S,N,CARDNO $
37 LABEL   LBL1 $
38 EQUIV   KGGX,KGG/NOGENL $
39 COND    LBL11,NOGENL $
40 SMA3    GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $
41 LABEL   LBL11 $
42 PARAM   //*MPY*/NSKIP/0/0 $
43 GP4     CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,YS,USET,ASET/
           LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/S,N,
           NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/ S,Y,
           AUTOSPC $
44 COND    ERROR6,NOL $
45 PARAM   //*AND*/NOSR/SINGLE/REACT $
46 PURGE   GM/MPCF1/GO,KOO,LOO,PO,UOOV,RUOV/OMIT/PS,KFS,KSS,KDFS/SINGLE/
           QG/NOSR $
47 COND    LBL4D,REACT $
48 JUMP    ERROR2 $
49 LABEL   LBL4D $
50 COND    LBL4,GENEL $
51 PARAM   //*EQ*/GPSPFLG/AUTOSPC/0 $
52 COND    LBL4,GPSPFLG $
53 GPSP    GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
54 OFP     OGPST,,,,,//S,N,CARDNO $
55 LABEL   LBL4 $
56 EQUIV   KGG,KNN/MPCF1 $
57 COND    LBL2,MPCF1 $
58 MCE1    USET,RG/GM $
59 MCE2    USET,GM,KGG,,,/KNN,,, $
60 LABEL   LBL2 $
61 EQUIV   KNN,KFF/SINGLE $
62 COND    LBL3,SINGLE $
63 SCE1    USET,KNN,,,/KFF,KFS,KSS,,, $
64 LABEL   LBL3 $
65 EQUIV   KFF,KAA/OMIT $
```

RIGID FORMAT DMAP LISTING
RELEASE APR. 1984

DISPLACEMENT APPROACH, RIGID FORMAT 5

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
 66  COND     LBL5,OMIT $
 67  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
 68  LABEL    LBL5 $
 69  RBMG2    KAA/LLL $
 70  SSG1     SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,CASECC,DIT,/PG,,,,/
              LUSET/1 $
 71  EQUIV    PG,PL/NOSET $
 72  COND     LBL10,NOSET $
 73  SSG2     USET,GM,YS,KFS,GO,,PG/,PO,PS,PL $
 74  LABEL    LBL10 $
 75  SSG3     LLL,KAA,PL,LOO,KOO,PO/ULV,UOOV,RULV,RUOV/OMIT/V,Y,IRES=-1/ 1/S,
              N,EPSI $
 76  COND     LBL9,IRES $
 77  MATGPR   GPL,USET,SIL,RULV//*L* $
 78  MATGPR   GPL,USET,SIL,RUOV//*O* $
 79  LABEL    LBL9 $
 80  SDR1     USET,PG,ULV,UOOV,YS,GO,GM,PS,KFS,KSS,/UGV,PGG,QG/1/*BKL0* $
 81  SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QG,UGV,EST,,PGG/
              OPG1,OQG1,OUGV1,OES1,OEF1,PUGV1/*BKL0* $
 82  OFP      OUGV1,OPG1,OQG1,OEF1,OES1,//S,N,CARDNO $
 83  COND     P2,JUMPPLOT $
 84  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUGV1,,GPECT,OES1/
              PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $
 85  PRTMSG   PLOTX2// $
 86  LABEL    P2 $
 87  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/X1,X2,X3,ECPT,GPCT/LUSET/   NOSIMP/
              0/NOGENL/GENEL $
 88  DSMG1    CASECC,GPTT,SIL,EDT,UGV,CSTM,MPT,ECPT,GPCT,DIT/KDGG/   DSCOSET $
 89  EQUIV    KDGG,KDNN/MPCF1 $
 90  COND     LBL2D,MPCF1 $
 91  MCE2     USET,GM,KDGG,,,/KDNN,,, $
 92  LABEL    LBL2D $
 93  EQUIV    KDNN,KDFF/SINGLE $
 94  COND     LBL3D,SINGLE $
 95  SCE1     USET,KDNN,,,/KDFF,KDFS,,,, $
 96  LABEL    LBL3D $
 97  EQUIV    KDFF,KDAA/OMIT $
 98  COND     LBL5D,OMIT $
 99  SMP2     USET,GO,KDFF/KDAA $
100  LABEL    LBL5D $
```

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```
101  ADD      KDAA,/KDAAM/(-1.0,0.0)/(0.0,0.0) $
102  DPD      DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,,,,,,,EED,EQDYN/  LUSET/
              LUSETD/NOTFL/NODLT/NOPSDL/NOFRL/  NONLFT/NOTRL/S,N,NOEED//
              NOUE $
103  COND     ERROR3,NOEED $
104  PARAM    //*MPY*/NEIGV/1/-1 $
105  READ     KAA,KDAAM,,,EED,USET,CASECC/LAMA,PHIA,,OEIGS/*BUCKLING*/   S,N,
              NEIGV/2 $
106  OFP      OEIGS,LAMA,,,,//S,N,CARDNO $
107  COND     ERROR4,NEIGV $
108  SDR1     USET,,PHIA,,,GO,GM,,KFS,,/PHIG,,BQG/1/*BKL1* $
109  SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,,,BGPDP,LAMA,BQG,PHIG,EST,,/,
              OBQG1,OPHIG,OBES1,OBEF1,PPHIG/*BKL1* $
110  OFP      OPHIG,OBQG1,OBEF1,OBES1,,//S,N,CARDNO $
111  COND     P3,JUMPPLOT $
112  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,,PPHIG,GPECT,
              OBES1/PLOTX3/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $
113  PRTMSG   PLOTX3// $
114  LABEL    P3 $
115  JUMP     FINIS $
116  LABEL    ERROR1 $
117  PRTPARM  //-1/*BUCKLING* $
118  LABEL    ERROR2 $
119  PRTPARM  //-2/*BUCKLING* $
120  LABEL    ERROR3 $
121  PRTPARM  //-3/*BUCKLING* $
122  LABEL    ERROR4 $
123  PRTPARM  //-4/*BUCKLING* $
124  LABEL    ERROR5 $
125  PRTPARM  //-5/*BUCKLING* $
126  LABEL    ERROR6 $
127  PRTPARM  //-6/*BUCKLING* $
128  LABEL    FINIS $
129  PURGE    DUMMY/MINUS1 $
130  END      $
```

3.6.2 Description of DMAP Operations for Buckling Analysis

5. GP1 generates coordinate system transformation matrices, tables of grid point locations and tables relating the internal and external grid point numbers.

6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

7. GP2 generates Element Connection Table with internal indices.

10. Go to DMAP No. 18 if there are no structure plot requests.

11. PLTSET transforms user input into a form used to drive the structure plotter.

12. PRTMSG prints error messages associated with the structure plotter.

15. Go to DMAP No. 18 if no undeformed structure plots are requested.

16. PLØT generates all requested undeformed structure plots.

17. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

19. GP3 generates Static Loads Table and Grid Point Temperature Table.

21. TA1 generates element tables for use in matrix assembly and stress recovery.

22. Go to DMAP No. 116 and print Error Message No. 1 if no structural elements have been defined.

25. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

27. Go to DMAP No. 29 if no stiffness matrix is to be assembled.

28. EMA assembles stiffness matrix $[K^x_{gg}]$ and Grid Point Singularity Table.

30. Go to DMAP No. 32 if no mass matrix is to be assembled.

31. EMA assembles mass matrix $[M_{gg}]$.

33. Go to DMAP No. 37 if no weight and balance information is requested.

34. Go to DMAP No. 124 and print Error Message No. 5 if no mass matrix exists.

35. GPWG generates weight and balance information.

36. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

38. Equivalence $[K^x_{gg}]$ to $[K_{gg}]$ if there are no general elements.

39. Go to DMAP No. 41 if there are no general elements.

40. SMA3 adds general elements to $[K^x_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

43. GP4 generates flags defining members of various displacement sets (USET), forms multipoint constraint equations $[R_g]\{u_g\} = 0$ and forms enforced displacement vector $\{Y_s\}$.

44. Go to DMAP No. 126 and print Error Message No. 6 if no independent degrees of freedom are defined.

47. Go to DMAP No. 49 if there are no free-body supports.

48. Go to DMAP No. 118 and print Error Message No. 2.

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50. Go to DMAP No. 55 if general elements are present.

52. Go to DMAP No. 55 if no potential grid point singularities exist.

53. GPSP generates a table of potential grid point singularities.

54. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

56. Equivalence $[K_{gg}]$ to $[K_{nn}]$ if there are no multipoint constraints.

57. Go to DMAP No. 60 if there are no multipoint constraints.

58. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

59. MCE2 partitions stiffness matrix

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right]$$

and performs matrix reduction

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m].$$

61. Equivalence $[K_{nn}]$ to $[K_{ff}]$ if no single-point constraints exist.

62. Go to DMAP No. 64 if no single-point constraints exist.

63. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right].$$

65. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

66. Go to DMAP No. 68 if no omitted coordinates exist.

67. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right],$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

69. RMBG2 decomposes constrained stiffness matrix $[K_{aa}] = [L_{\ell\ell}][U_{\ell\ell}]$.

70. SSG1 generates static load vectors $\{P_g\}$.

71. Equivalence $\{P_g\}$ to $\{P_\ell\}$ if no constraints are applied.

72. Go to DMAP No. 74 if no constraints are applied.

73. SSG2 applies constraints to static load vectors

$$\{P_g\} = \left\{\frac{\bar{P}_n}{P_m}\right\} , \qquad \{P_n\} = \{\bar{P}_n\} + [G_m^T]\{P_m\} ,$$

$$\{P_n\} = \left\{\frac{\bar{P}_f}{P_s}\right\} , \qquad \{P_f\} = \{\bar{P}_f\} - [K_{fs}]\{Y_s\}$$

and $$\{P_f\} = \left\{\frac{P_a}{P_o}\right\} \text{ and } \qquad \{P_\ell\} = \{P_a\} + [G_o^T]\{P_o\} .$$

75. SSG3 solves for displacements of independent coordinates

$$\{u_\ell\} = [K_{\ell\ell}]^{-1}\{P_\ell\} ,$$

solves for displacements of omitted coordinates

$$\{u_o^o\} = [K_{oo}]^{-1}\{P_o\} ,$$

calculates residual vector (RULV) and residual vector error ratio for independent coordinates

$$\{\delta P_\ell\} = \{P_\ell\} - [K_{\ell\ell}]\{u_\ell\} ,$$

$$\varepsilon_\ell = \frac{\{u_\ell^T\}\{\delta P_\ell\}}{\{P_\ell^T\}\{u_\ell\}}$$

and calculates residual vector (RUØV) and residual vector error ratio for omitted coordinates

$$\{\delta P_o\} = \{P_o\} - [K_{oo}]\{u_o^o\} ,$$

$$\varepsilon_o = \frac{\{u_o^T\}\{\delta P_o\}}{\{P_o^T\}\{u_o^o\}} .$$

76. Go to DMAP No. 79 if residual vectors are not to be printed.

77. MATGPR prints the residual vector for independent coordinates (RULV).

78. MATGPR prints the residual vector for omitted coordinates (RUØV).

80. SDR1 recovers dependent displacements

$$\{u_o\} = [G_o]\{u_\ell\} + \{u_o^o\} \ ,$$

$$\begin{Bmatrix} u_a \\ \hline u_o \end{Bmatrix} = \{u_f\} \ , \qquad \begin{Bmatrix} u_f \\ \hline Y_s \end{Bmatrix} = \{u_n\} \ ,$$

$$\{u_m\} = [G_m]\{u_n\} \ , \qquad \begin{Bmatrix} u_n \\ \hline u_m \end{Bmatrix} = \{u_g\}$$

and recovers single-point forces of constraint

$$\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\} + [K_{ss}]\{Y_s\}.$$

81. SDR2 calculates element forces(ØEF1) and stresses (ØES1) and prepares load vectors (ØPG1), displacement vectors (ØUGV1) and single-point forces of constraint (ØQG1) for output and translation components of the displacement vector (PUGV1) for the static solution.

82. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

83. Go to DMAP No. 86 if no static solution deformed structure plots are requested.

84. PLØT generates all requested static solution deformed structure and contour plots.

85. PRTMSG prints plotter data, engineering data, and contour data for each static solution deformed plot generated.

87. TA1 generates element tables for use in differential stiffness matrix assembly.

88. DSMG1 generates differential stiffness matrix $[K_{gg}^d]$.

89. Equivalence $[K_{gg}^d]$ to $[K_{nn}^d]$ if no multipoint constraints exist.

90. Go to DMAP No. 92 if no multipoint constraints exist.

91. MCE2 partitions differential stiffness matrix

$$[K_{gg}^d] = \left[\begin{array}{c|c} \bar{K}_{nn}^d & K_{nm}^d \\ \hline K_{mn}^d & K_{mm}^d \end{array}\right]$$

and performs matrix reduction

$$[K_{nn}^d] = [\bar{K}_{nn}^d] + [G_m^T][K_{mn}^d] + [K_{mn}^d][G_m] + [G_m^T][K_{mm}^d][G_m].$$

93. Equivalence $[K_{nn}^d]$ to $[K_{ff}^d]$ if no single-point constraints exist.

94. Go to DMAP No. 96 if no single-point constraints exist.

95. SCE1 partitions out single-point constraints

$$[K^d_{nn}] = \left[\begin{array}{c|c} K^d_{ff} & K^d_{fs} \\ \hline K^d_{sf} & K^d_{ss} \end{array}\right] .$$

97. Equivalence $[K^d_{ff}]$ to $[K^d_{aa}]$ if no omitted coordinates exist.

98. Go to DMAP No. 100 if no omitted coordinates exist.

99. SMP2 partitions constrained differential stiffness matrix

$$[K^d_{ff}] = \left[\begin{array}{c|c} \bar{K}^d_{aa} & K^d_{ao} \\ \hline K^d_{oa} & K^d_{oo} \end{array}\right] .$$

and performs matrix reduction

$$[K^d_{aa}] = [\bar{K}^d_{aa}] + [K^d_{oa}]^T[G_o] + [G_o]^T[K^d_{oa}] + [G_o]^T[K^d_{oo}][G_o].$$

101. ADD $-[K^d_{aa}]$ and nothing to create $[K^{dm}_{aa}]$.

102. DPD extracts Eigenvalue Extraction Data from Dynamics data block.

103. Go to DMAP No. 120 and print Error Message No. 3 if there is no Eigenvalue Extraction Data.

105. READ extracts real eigenvalues and eigenvectors from the equation

$$[K_{aa} + \lambda K^{dm}_{aa}]\{u_a\} = 0$$

and normalizes eigenvectors according to one of the following user requests:

1) Unit value of a selected component
2) Unit value of the largest component.

106. ØFP formats the eigenvalues (LAMA) and summary of eigenvalue extraction information (ØEIGS) prepared by READ and places them on the system output file for printing.

107. Go to DMAP No. 122 and print Error Message No. 4 if no eigenvalues were found.

108. SDR1 recovers dependent components of the eigenvectors

$$\{\phi_o\} = [G_o]\{\phi_a\} , \qquad \left\{\begin{array}{c} \phi_a \\ \hline \phi_o \end{array}\right\} = \{\phi_f\} ,$$

$$\left\{\begin{array}{c} \phi_f \\ \hline \phi_s \end{array}\right\} = \{\phi_n\} , \qquad \{\phi_m\} = [G_m]\{\phi_n\} ,$$

$$\left\{\begin{array}{c} \phi_n \\ \hline \phi_m \end{array}\right\} = \{\phi_g\}$$

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and recovers single-point forces of constraint $\{q_s\} = [K_{fs}^T] \{\phi_f\}$.

109. SDR2 calculates element forces (ØBEF1) and stresses (ØBES1) and prepares eigenvectors (ØPHIG) and single-point forces of constraint (ØBQG1) for output and translation components of the eigenvectors (PPHIG) for the buckling solution.

110. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

111. Go to DMAP No. 114 if no buckling solution deformed structure plots are requested.

112. PLØT generates all requested buckling solution deformed structure and contour plots.

113. PRTMSG prints plotter data, engineering data, and contour data for each buckling solution deformed plot generated.

115. Go to DMAP No. 128 and make normal exit.

117. Print Error Message No. 1 and terminate execution.

119. Print Error Message No. 2 and terminate execution.

121. Print Error Message No. 3 and terminate execution.

123. Print Error Message No. 4 and terminate execution.

125. Print Error Message No. 5 and terminate execution.

127. Print Error Message No. 6 and terminate execution.

3.6.3 Output for Buckling Analysis

The summary of the eigenvalues associated with the buckling modes and the summary of the eigenvalue analysis performed, as described in the Normal Mode Analysis rigid format (see Section 3.4.3), are automatically printed.

The following output may be requested:

1. Displacements and nonzero components of the static loads and single-point forces of constraint at selected grid points for the static analysis.
2. Forces and stresses in selected elements for the static loading condition.
3. Mode shapes and nonzero components of the single-point forces of constraint at selected grid points for selected modes.
4. Undeformed plot of the structural model and mode shapes for selected buckling modes.
5. Contour plots of stresses and displacements for selected buckling modes.

3.6.4 Case Control Deck for Buckling Analysis

The following items relate to subcase definition and data selection for Buckling Analysis:

1. The Case Control Deck must contain at least two subcases. Subcases beyond the second are used only for output selection.
2. METHØD must appear in the second subcase to select an EIGB card from the Bulk Data Deck.
3. A static loading condition must be defined in the first subcase with a LØAD, TEMPERATURE (LØAD), or DEFØRM selection, unless all loading is specified by grid point displacements on SPC cards.
4. An SPC set must be selected above the subcase level, unless all constraints are specified on GRID cards.
5. Output requests that apply only to the solution under static load must be placed in the first subcase.
6. Output requests that apply to the buckling solution only must be placed in the second and succeeding subcases. If only two subcases exist, the output requests in the second subcase will be honored for all buckling modes.
7. Output requests that apply to both the static solution and the buckling modes may be placed above the subcase level.

3.6.5 Parameters for Buckling Analysis

The following parameters are used in Buckling Analysis:

1. GRDPNT - optional. A positive integer value of this parameter will cause the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed.

2. WTMASS - optional. The terms of the mass matrix are multiplied by the real value of this parameter when they are generated in EMA.

3. IRES - optional. A positive integer value of this parameter will cause the printing of the residual vectors following the execution of SSG3.

4. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters will cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.

5. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.

6. AUTØSPC - reserved for future optional use. The default value is -1.

3.6.6 Optional Diagnostic Output for FEER

Special detailed information obtained by requesting DIAG 16 in the Executive Control Deck is the same as that described under Normal Mode Analysis (see Section 3.4.6).

3.6.7 Rigid Format Error Messages from Buckling Analysis

The following fatal errors are detected by the DMAP statements in the Buckling Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

BUCKLING ANALYSIS ERRØR MESSAGE NØ. 1 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

BUCKLING ANALYSIS ERRØR MESSAGE NØ. 2 - FREE BØDY SUPPØRTS NØT ALLØWED.

Free bodies are not allowed in Buckling Analysis. The SUPØRT cards must be removed from the Bulk Data Deck and other constraints applied if required for stability.

BUCKLING ANALYSIS ERRØR MESSAGE NØ. 3 - EIGENVALUE EXTRACTIØN DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGB card in the Bulk Data Deck and METHØD in the Case Control Deck must select an EIGB set.

BUCKLING ANALYSIS ERRØR MESSAGE NØ. 4 - NØ EIGENVALUES FØUND.

No buckling modes exist in the range specified by the user.

BUCKLING ANALYSIS ERRØR MESSAGE NØ 5 - MASS MATRIX REQUIRED FØR WEIGHT AND BALANCE CALCULATIØNS.

The mass matrix is null because either no elements were defined with Connection cards, nonstructural mass was not defined on a Property card or the density was not defined on a Material card.

BUCKLING ANALYSIS ERRØR MESSAGE NØ. 6 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

3.7 PIECEWISE LINEAR STATIC ANALYSIS

3.7.1 DMAP Sequence for Piecewise Linear Static Analysis.

```
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OPTIONS IN EFFECT   GO      ERR=2   LIST    NODECK  NOREF   NOOSCAR

   1  BEGIN     DISP 06 - PIECEWISE LINEAR STATIC ANALYSIS - APR. 1984 $
   2  PRECHK    ALL $
   3  FILE      QG1=APPEND/UGV1=APPEND/KGGSUM=SAVE/PGV1=APPEND $
   4  PARAM     //*MPY*/CARDNO/0/0 $
   5  GP1       GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  NOGPDT/
                MINUS1=-1 $
   6  PLTTRAN   BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $
   7  GP2       GEOM2,EQEXIN/ECT $
   8  PARAML    PCDB//*PRES*////JUMPPLOT $
   9  PURGE     PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $
  10  COND      P1,JUMPPLOT $
  11  PLTSET    PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/   S,N,
                JUMPPLOT $
  12  PRTMSG    PLTSETX// $
  13  PARAM     //*MPY*/PLTFLG/1/1 $
  14  PARAM     //*MPY*/PFILE/0/0 $
  15  COND      P1,JUMPPLOT $
  16  PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
                NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $
  17  PRTMSG    PLOTX1// $
  18  LABEL     P1 $
  19  GP3       GEOM3,EQEXIN,GEOM2/SLT,GPTT/S,N,NOGRAV $
  20  PARAM     //*AND*/SKPMGG/NOGRAV/V,Y,GRDPNT $
  21  TA1       ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,ECPT,GPCT/LUSET/S,N,
                NOSIMP/2/S,N,NOGENL/S,N,GENEL $
  22  PARAM     //*AND*/NOELMT/NOGENL/NOSIMP $
  23  COND      ERROR4,NOELMT $
  24  PURGE     KGGX,GPST/NOSIMP/OGPST/GENEL $
  25  COND      LBL1,NOSIMP $
  26  PARAM     //*ADD*/NOKGGX/1/0 $
  27  PARAM     //*ADD*/NOMGG/1/0 $
  28  EMG       EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,/S,N,NOKGGX/ S,
                N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/  C,Y,CPQUAD1/C,Y,
                CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/C,Y,CPTUBE/ C,Y,CPQDPLT/C,Y,
                CTRPLT/C,Y,CPTRBSC $
  29  PURGE     KGGX,GPST/NOKGGX/MGG/NOMGG $
```

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```
30  COND     JMPKGG,NOKGGX $
31  EMA      GPECT,KDICT,KELM/KGGX,GPST $
32  LABEL    JMPKGG $
33  COND     JMPMGG,NOMGG $
34  EMA      GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $
35  LABEL    JMPMGG $
36  COND     LBL1,GRDPNT $
37  COND     ERROR3,NOMGG $
38  GPWG     BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/V,Y,WTMASS $
39  OFP      OGPWG,,,,,//S,N,CARDNO $
40  LABEL    LBL1 $
41  PLA1     CSTM,MPT,ECPT,GPCT,DIT,CASECC,EST/KGGXL,ECPTNL,ESTL,ESTNL/S,N,
             KGGLPG/S,N,NPLALIM/S,N,ECPTNLPG/S,N,PLSETNO/S,N,NONLSTR/S,N,
             PLFACT $
42  COND     ERROR1,ECPTNLPG $
43  PURGE    ONLES,ESTNL1/NONLSTR $
44  PARAM    //*ADD*/ALWAYS/-1/0 $
45  PARAM    //*ADD*/NEVER/1/0 $
46  EQUIV    KGGX,KGG/NOGENL/KGGXL,KGGL/NOGENL $
47  COND     LBL11,NOGENL $
48  SMA3     GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $
49  SMA3     GEI,KGGXL/KGGL/LUSET/NOGENL/KGGLPG $
50  LABEL    LBL11 $
51  PARAM    //*MPY*/NSKIP/0/0 $
52  GP4      CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,YS,USET,ASET/
             LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/S,N,
             NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/ S,Y,
             AUTOSPC $
53  PARAM    //*AND*/NOSR/SINGLE/REACT $
54  PURGE    KRR,KLR,QR,DM/REACT/GM/MPCF1/GO,KOO,LOO,PO,UOOV,RUOV/OMIT/PS,
             KFS,KSS/SINGLE/QG/NOSR $
55  SSG1     SLT,BGPDT,CSTM,SIL,EST,MPT,,MGG,CASECC,DIT,/PG1,,,,/LUSET/1 $
56  EQUIV    PG1,PL/NOSET $
57  COND     LBL4,GENEL $
58  PARAM    //*EQ*/GPSPFLG/AUTOSPC/0 $
59  COND     LBL4,GPSPFLG $
60  GPSP     GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
61  OFP      OGPST,,,,,//S,N,CARDNO $
62  LABEL    LBL4 $
63  PARAM    //*ADD*/PLACOUNT/1/0 $
```

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```
 64  EQUIV    KGG,KNN/MPCF1 $
 65  COND     LBL2,MPCF1 $
 66  MCE1     USET,RG/GM $
 67  LABEL    LOOPBGN $                    Top of Load Increment Loop
 68  EQUIV    KGG,KNN/MPCF1 $
 69  COND     LBL2,MPCF1 $
 70  MCE2     USET,GM,KGG,,,/KNN,,, $
 71  LABEL    LBL2 $
 72  EQUIV    KNN,KFF/SINGLE $
 73  COND     LBL3,SINGLE $
 74  SCE1     USET,KNN,,,/KFF,KFS,KSS,,, $
 75  LABEL    LBL3 $
 76  EQUIV    KFF,KAA/OMIT $
 77  COND     LBL5,OMIT $
 78  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
 79  LABEL    LBL5 $
 80  EQUIV    KAA,KLL/REACT $
 81  COND     LBL6,REACT $
 82  RBMG1    USET,KAA,/KLL,KLR,KRR,,, $
 83  LABEL    LBL6 $
 84  DECOMP   KLL/LLL,/1/0/MINDIAGK/DETKLLXX/IDETKLLX/ S,N,SINGKLLX $
 85  COND     PLALBL4,SINGKLLX $
 86  COND     LBL7,REACT $
 87  RBMG3    LLL,KLR,KRR/DM $
 88  LABEL    LBL7 $
 89  ADD      PG1,/PG/PLFACT $
 90  COND     LBL10,NOSET $
 91  SSG2     USET,GM,YS,KFS,GO,DM,PG/QR,PO,PS,PL $
 92  LABEL    LBL10 $
 93  SSG3     LLL,KLL,PL,LOO,KOO,PO/ULV,UOOV,RULV,RUOV/OMIT/V,Y,IRES=-1/
              PLACOUNT/S,N,EPSI $
 94  COND     LBL9,IRES $
 95  MATGPR   GPL,USET,SIL,RULV//*L* $
 96  MATGPR   GPL,USET,SIL,RUOV//*O* $
 97  LABEL    LBL9 $
 98  SDR1     USET,PG,ULV,UOOV,YS,GO,GM,PS,KFS,KSS,QR/DELTAUGV,DELTAPG,
              DELTAQG/1/*STATICS* $
 99  PLA2     DELTAUGV,DELTAPG,DELTAQG/UGV1,PGV1,QG1/S,N,PLACOUNT $
100  EQUIV    ESTNL,ESTNL1/NEVER/ECPTNL,ECPTNL1/NEVER $
```

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```
101  COND     PLALBL2A,NONLSTR $
102  PLA3     CSTM,MPT,DIT,DELTAUGV,ESTNL,CASECC/ONLES,ESTNL1/PLACOUNT/
              PLSETNO $
103  OFP      ONLES,,,,,//S,N,CARDNO $
104  LABEL    PLALBL2A $
105  PARAM    //*SUB*/DIFF/NPLALIM/PLACOUNT $
106  COND     PLALBL5,DIFF $
107  PLA4     CSTM,MPT,ECPTNL,GPCT,DIT,DELTAUGV/KGGNL,ECPTNL1/S,N,PLACOUNT/S,
              N,PLSETNO/S,N,PLFACT $
108  EQUIV    KGGNL,KGGSUM/KGGLPG $
109  COND     PLALBL3,KGGLPG $
110  ADD      KGGNL,KGGL/KGGSUM $
111  LABEL    PLALBL3 $
112  EQUIV    ESTNL1,ESTNL/ALWAYS/ECPTNL1,ECPTNL/ALWAYS/KGGSUM,KGG/ALWAYS $
113  REPT     LOOPBGN,360 $
114  JUMP     ERROR2 $                          Bottom of Load Increment Loop
115  LABEL    PLALBL4 $
116  PRTPARM  //-5/*PLA* $
117  LABEL    PLALBL5 $
118  SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QG1,UGV1,ESTL,,
              PGV1/OPG1,OQG1,OUGV1,OES1,OEF1,PUGV1/*PLA* $
119  OFP      OUGV1,OPG1,OQG1,OEF1,OES1,//S,N,CARDNO $
120  COND     P2,JUMPPLOT $
121  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUGV1,,ECPT,OES1/
              PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $
122  PRTMSG   PLOTX2// $
123  LABEL    P2 $
124  JUMP     FINIS $
125  LABEL    ERROR1 $
126  PRTPARM  //-1/*PLA* $
127  LABEL    ERROR2 $
128  PRTPARM  //-2/*PLA* $
129  LABEL    ERROR3 $
130  PRTPARM  //-3/*PLA* $
131  LABEL    ERROR4 $
132  PRTPARM  //-4/*PLA* $
133  LABEL    FINIS $
134  PURGE    DUMMY/MINUS1 $
135  END      $
```

3.7.2 Description of DMAP Operations for Piecewise Linear Static Analysis

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

7. GP2 generates Element Connection Table with internal indices.

10. Go to DMAP No. 18 if there are no structure plot requests.

11. PLTSET transforms user intput into a form used to drive the structure plotter.

12. PRTMSG prints error messages associated with the structure plotter.

15. Go to DMAP No. 18 if no undeformed structure plots are requested.

16. PLØT generates all requested undeformed structure plots.

17. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

19. GP3 generates Static Loads Table and Grid Point Temperature Table.

21. TA1 generates element tables for use in matrix assembly and stress recovery.

23. Go to DMAP No. 131 and print Error Message No. 4 if no elements have been defined.

25. Go to DMAP No. 40 if there are no structural elements.

28. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

30. Go to DMAP No. 32 if no stiffness matrix is to be assembled.

31. EMA assembles stiffness matrix $[K_{gg}^{x}]$ and Grid Point Singularity Table.

33. Go to DMAP No. 35 if no mass matrix is to be assembled.

34. EMA assembles mass matrix $[M_{gg}]$.

36. Go to DMAP No. 40 if no weight and balance information is requested.

37. Go to DMAP No. 129 and print Error Message No. 3 if no mass matrix exists.

38. GPWG generates weight and balance information.

39. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

41. PLA1 extracts the linear terms from $[K_{gg}^{x}]$ to give $[K_{gg}^{x\ell}]$, extracts the nonlinear entries from the Element Connection and Properties Table to give ECPTNL, and separates the linear and nonlinear entries in the Element Summary Table to give ESTL and ESTNL.

42. Go to DMAP No. 125 and print Error Message No. 1 if no elements have a stress-dependent modulus of elasticity.

46. Equivalence $[K_{gg}^{x}]$ to $[K_{gg}]$ and $[K_{gg}^{x\ell}]$ to $[K_{gg}^{\ell}]$ if there are no general elements.

47. Go to DMAP No. 50 if there are no general elements.

48. SMA3 adds general elements to $[K_{gg}^{x}]$ to obtain stiffness matrix $[K_{gg}]$.

49. SMA3 adds general elements to $[K_{gg}^{x\ell}]$ to obtain stiffness matrix of linear elements $[K_{gg}^{\ell}]$.

52. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations $[R_g]\{u_g\} = 0$.

55. SSG1 generates total static load vector $\{P_g^1\}$.

56. Equivalence $\{P_g^1\}$ to $\{P_\ell\}$ if no constraints are applied.

57. Go to DMAP No. 62 ig general elements are present.

59. Go to DMAP No. 62 if no potential grid point singularities exist.

60. GPSP generates a table of potential grid point singularities.

61. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

64. Equivalence $[K_{gg}]$ to $[K_{nn}]$ if no multipoint constraints exist.

65. Go to DMAP No. 71 if no multipoint constraints exist.

66. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

67. Beginning of loop for additional load increments.

68. Equivalence $[K_{gg}]$ to $[K_{nn}]$ if no multipoint constraints exist.

69. Go to DMAP No. 71 if no multipoint constraints exist.

70. MCE2 partitions stiffness matrix

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right]$$

and performs matrix reduction

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m].$$

72. Equivalence $[K_{nn}]$ to $[K_{ff}]$ if no single-point constraints exist.

73. Go to DMAP No. 75 if no single-point constraints exist.

74. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right].$$

76. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

77. Go to DMAP No. 79 if no omitted coordinates exist.

78. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right],$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

80. Equivalence $[K_{aa}]$ to $[K_{\ell\ell}]$ if no free-body supports exist.

81. Go to DMAP No. 83 if no free-body supports exist.

82. RBMG1 partitions out free-body supports

$$[K_{aa}] = \left[\begin{array}{c|c} K_{\ell\ell} & K_{\ell r} \\ \hline K_{r\ell} & K_{rr} \end{array}\right]$$

84. DECØMP decomposes constrained stiffness matrix $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$.

85. Go to DMAP No. 115 and print Error Message No. 5 if stiffness matrix $[K_{\ell\ell}]$ is singular (i.e., local plasticity).

86. Go to DMAP No. 88 if no free-body supports exist.

87. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}],$$

calculates rigid body check matrix

$$[X] = [K_{rr}]^T + [K_{\ell r}][D]$$

and calculates rigid body error ratio

$$\varepsilon = \frac{||X||}{||K_{rr}||} .$$

89. ADD multiplies total load vector $\{P_g^1\}$ by factor, PLFACT, and adds it to nothing to obtain applied load vector $\{P_g\}$ for current loop.

90. Go to DMAP No. 92 if no constraints are applied.

91. SSG2 applies constraints to static load vectors for current loop

$$\{P_g\} = \left\{\begin{array}{c} \bar{P}_n \\ \hline P_m \end{array}\right\}, \qquad \{P_n\} = \{\bar{P}_n\} + [G_m^T]\{P_m\} ,$$

$$\{P_n\} = \left\{\begin{array}{c} \bar{P}_f \\ \hline P_s \end{array}\right\}, \qquad \{P_f\} = \{\bar{P}_f\} - [K_{fs}]\{Y_s\} ,$$

$$\{P_f\} = \left\{\begin{array}{c}\bar{P}_a \\ \hline P_o\end{array}\right\} , \qquad \{P_a\} = \{\bar{P}_a\} + [G_o^T]\{P_o\} ,$$

$$\{P_a\} = \left\{\begin{array}{c}P_\ell \\ \hline P_r\end{array}\right\}$$

and calculates incremental determinate forces of reaction for current loop

$$\{q_r\} = -\{P_r\} - [D^T]\{P_\ell\}.$$

93. SSG3 solves for displacements of independent coordinates

$$\{u_\ell\} = [K_{\ell\ell}]^{-1}\{P_\ell\} ,$$

solves for displacements of omitted coordinates

$$\{u_o^o\} = [K_{oo}]^{-1}\{P_o\} ,$$

calculates residual vector (RULV) and residual vector error ratio for independent coordinates

$$\{\delta P_\ell\} = \{P_\ell\} - [K_{\ell\ell}]\{u_\ell\} ,$$

$$\varepsilon_\ell = \frac{\{u_\ell^T\}\{\delta P_\ell\}}{\{P_\ell^T\}\{u_\ell\}}$$

and calculates residual vector (RUØV) and residual vector error ratio for omitted coordinates

$$\{\delta P_o\} = \{P_o\} - [K_{oo}]\{u_o^o\} ,$$

and $$\varepsilon_o = \frac{\{u_o^T\}\{\delta P_o\}}{\{P_o^T\}\{u_o^o\}}$$

94. Go to DMAP No. 97 if residual vectors are not to be printed.

95. MATGPR prints the residual vector for independent coordinates (RULV).

96. MATGPR prints the residual vector for omitted coordinates (RUØV).

98. SDR1 recovers dependent displacements for current loop

$$\left\{\frac{u_\ell}{u_r}\right\} = \{u_a\} \qquad \{u_o\} = [G_o]\{u_a\} + \{u_o^o\} ,$$

$$\left\{\frac{u_a}{u_o}\right\} = \{u_f\} , \qquad \left\{\frac{u_f}{Y_s}\right\} = \{u_n\} ,$$

$$\{u_m\} = [G_m]\{u_n\} , \qquad \left\{\frac{u_n}{u_m}\right\} = \{u_g\}$$

and recovers single-point forces of constraint for current loop

$$\{\delta q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\}.$$

99. PLA2 adds the incremental displacement vector (DELTAUGV) and the incremental single-point forces of constraint vector (DELTAQG) for the current loop to the accumulated sum of these vectors (DELTAPG).

$$\{u_{g_{i+1}}\} = \{\delta u_{g_i}\} + \{u_{g_i}\} \quad \text{and}$$

$$\{q_{g_{i+1}}\} = \{\delta q_{g_i}\} + \{q_{g_i}\} .$$

100. Allocate separate files for ESTNL and ESTNL1 and for ECPTNL and ECPTNL1.

101. Go to DMAP No. 104 if no stress output is requested for nonlinear elements.

102. PLA3 calculates incremental stresses in nonlinear elements (ØNLES) for which an output request has been made and updates the accumulated stresses (ESTNL1) in these elements.

103. ØFP formats the accumulated stresses in nonlinear elements prepared by PLA3 and places them on the system output file for printing.

106. Go to DMAP No. 117 if all loading increments have been completed.

107. PLA4 generates stiffness matrix for nonlinear elements $[K_{gg}^{n\ell}]$ and updates stress information.

108. Equivalence $[K_{gg}^{n\ell}]$ to $[K_{gg}]$ if all elements are nonlinear.

109. Go to DMAP No. 111 if all elements are nonlinear.

110. Add stiffness matrix for nonlinear elements (KGGNL) to stiffness matrix for linear elements (KGGL)

$$[K_{gg}^{n\ell}] + [K_{gg}^{\ell}] + [K_{gg}^{sum}]$$

112. Equivalence existing element tables to updated tables and equivalence $[K_{gg}^{sum}]$ to $[K_{gg}]$ for next pass through loop.

113. Go to DMAP No. 67 if additional load increments need to be processed.

114. Go to DMAP No. 127 and print Error Message No. 2 as the number of load increments exceeds 360.

116. Print Error Message No. 5 and terminate execution.

118. SDR2 calculates element forces (ØEF1) and stresses for linear elements (ØES1) and prepares load vectors (ØPG1), displacement vectors (ØUGV1) and single-point forces of constraint (ØQG1) for output and translation components of the displacement vector (PUGV1).

119. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

120. Go to DMAP No. 123 if no deformed structure plots are requested.

121. PLØT generates all requested deformed structure and contour plots.

122. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.

124. Go to DMAP No. 133 and make normal exit.

126. Print Error Message No. 1 and terminate execution.

128. Print Error Message No. 2 and terminate execution.

130. Print Error Message No. 3 and terminate execution.

132. Print Error Message No. 4 and terminate execution.

3.7.3 Output for Piecewise Linear Static Analysis

The following output may be requested for Piecewise Linear Static Analysis:

1. Accumulated sums of displacements and nonzero components of the static loads and single-point forces of constraint at selected grid points for each load increment.
2. Stresses in selected elements. If an element is composed of a nonlinear material, the accumulated stress will be output for each load increment. Stresses in linear elements are only calculated for the total load.
3. Undeformed plot of the structural model and deformed plots for each load increment.
4. Contour plots of stresses and displacements for each load increment.

3.7.4 Case Control Deck for Piecewise Linear Static Analysis

The following items relate to subcase definition and data selection for Piecewise Linear Static Analysis:

1. The Case Control Deck must contain one and only one subcase.
2. A static loading condition must be defined with a LØAD selection.
3. An SPC set must be selected unless all constraints are specified on GRID cards.
4. PLCØEFFICIENT must appear either to select a PLFACT set from the Bulk Data Deck or to explicitly select the default value of unity.

3.7.5 Parameters for Piecewise Linear Static Analysis

The following parameters are used in Piecewise Linear Static Analysis:

1. GRDPNT - optional. A positive integer value of this parameter will cause the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed.
2. WTMASS - optional. The terms of the mass matrix are multiplied by the real value of this parameter when they are generated in EMA.
3. IRES - optional. A positive integer value of this parameter will cause the printing of the residual vectors following the execution of SSG3.
4. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters will cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.

5. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.

6. AUTØSPC - reserved for future optional use. The default value is -1.

3.7.6 Rigid Format Error Messages from Piecewise Linear Static Analysis

The following fatal errors are detected by the DMAP statements in the Piecewise Linear Static Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

PIECEWISE LINEAR STATIC ANALYSIS ERRØR MESSAGE NØ. 1 - NØ NØNLINEAR ELEMENTS HAVE BEEN DEFINED.

A piecewise linear problem has not been formulated because none of the elements has a stress dependent modulus of elasticity defined on a Material card.

PIECEWISE LINEAR STATIC ANALYSIS ERRØR MESSAGE NØ. 2 - ATTEMPT TØ EXECUTE MØRE THAN 360 LØØPS.

An attempt has been made to use more than 360 load increments. This number may be increased by ALTERing the REPT instruction preceding SDR2.

PIECEWISE LINEAR STATIC ANALYSIS ERRØR MESSAGE NØ. 3 - MASS MATRIX REQUIRED FØR WEIGHT AND BALANCE CALCULATIØNS.

The mass matrix is null because either no elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

PIECEWISE LINEAR STATIC ANALYSIS ERRØR MESSAGE NØ. 4 - NØ ELEMENTS HAVE BEEN DEFINED.

No elements have been defined with either Connection cards or GENEL cards.

PIECEWISE LINEAR STATIC ANALYSIS ERRØR MESSAGE NØ. 5 - STIFFNESS MATRIX SINGULAR DUE TØ MATERIAL PLASTICITY.

The stiffness matrix is singular due either to one or more grid point singularities or element material plasticity.

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3.8 DIRECT COMPLEX EIGENVALUE ANALYSIS

3.8.1 DMAP Sequence for Direct Complex Eigenvalue Analysis

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OPTIONS IN EFFECT   GO     ERR=2   LIST    NODECK  NOREF   NOOSCAR

  1  BEGIN    DISP 07 - DIRECT COMPLEX EIGENVALUE ANALYSIS - APR. 1984 $
  2  PRECHK   ALL $
  3  FILE     GOD=SAVE/GMD=SAVE $
  4  PARAM    //*MPY*/CARDNO/0/0 $
  5  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  S,N,
              NOGPDT/MINUS1=-1 $
  6  PLTTRAN  BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $
  7  PURGE    USET,GM,GO,KAA,BAA,MAA,K4AA,KFS,EST,ECT,PLTSETX,PLTPAR,GPSETS,
              ELSETS/NOGPDT $
  8  COND     LBL5,NOGPDT $
  9  GP2      GEOM2,EQEXIN/ECT $
 10  PARAML   PCDB//*PRES*////JUMPPLOT $
 11  PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $
 12  COND     P1,JUMPPLOT $
 13  PLTSET   PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/,JUMNSIL/S,N,
              JUMPPLOT=-1 $
 14  PRTMSG   PLTSETX// $
 15  PARAM    //*MPY*/PLTFLG/1/1 $
 16  PARAM    //*MPY*/PFILE/0/0 $
 17  COND     P1,JUMPPLOT $
 18  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
              NSIL/LUSET/JUMPPLOT/PLTFLG/S,N,PFILE $
 19  PRTMSG   PLOTX1// $
 20  LABEL    P1 $
 21  GP3      GEOM3,EQEXIN,GEOM2/,GPTT/NOGRAV $
 22  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/LUSET/S,N,NOSIMP=
              -1/1/S,N,NOGENL=-1/S,N,GENEL $
 23  PURGE    K4GG,GPST,OGPST,MGG,BGG,K4NN,K4FF,K4AA,MNN,MFF,MAA,BNN,BFF,BAA,
              KGGX/NOSIMP / OGPST/GENEL $
 24  COND     LBL1,NOSIMP $
 25  PARAM    //*ADD*/NOKGGX/1/0 $
 26  PARAM    //*ADD*/NOMGG/1/0 $
 27  PARAM    //*ADD*/NOBGG=-1/1/0 $
 28  PARAM    //*ADD*/NOK4GG/1/0 $
 29  EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,BELM,BDICT/S,N,
              NOKGGX/S,N,NOMGG/S,N,NOBGG/S,N,NOK4GG//C,Y,COUPMASS/C,Y,CPBAR/
              C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/C,Y,
              CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC $
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```
30  PURGE   KGGX,GPST/NOKGGX/MGG/NOMGG $
31  COND    LBLKGGX,NOKGGX $
32  EMA     GPECT,KDICT,KELM/KGGX,GPST $
33  LABEL   LBLKGGX $
34  COND    LBLMGG,NOMGG $
35  EMA     GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $
36  LABEL   LBLMGG $
37  COND    LBLBGG,NOBGG $
38  EMA     GPECT,BDICT,BELM/BGG, $
39  LABEL   LBLBGG $
40  COND    LBLK4GG,NOK4GG $
41  EMA     GPECT,KDICT,KELM/K4GG,/NOK4GG $
42  LABEL   LBLK4GG $
43  PURGE   MNN,MFF,MAA/NOMGG $
44  PURGE   BNN,BFF,BAA/NOBGG $
45  COND    LBL1,GRDPNT $
46  COND    ERROR3,NOMGG $
47  GPWG    BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT/C,Y,WTMASS $
48  OFP     OGPWG,,,,,//S,N,CARDNO $
49  LABEL   LBL1 $
50  EQUIV   KGGX,KGG/NOGENL $
51  COND    LBL11,NOGENL $
52  SMA3    GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $
53  LABEL   LBL11 $
54  PARAM   //*MPY*/NSKIP/0/0 $
55  GP4     CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,USET,ASET/ LUSET/
            S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/S,N,NSKIP/S,
            N,REPEAT/S,N,NOSET=-1/S,N,NOL/S,N,NOA=-1/C,Y,ASETOUT/S,Y,
            AUTOSPC $
56  PURGE   GM,GMD/MPCF1/GO,GOD/OMIT/KFS,QPC/SINGLE $
57  COND    LBL4,GENELS
58  COND    LBL4,NOSIMP $
59  PARAM   //*EQ*/GPSPFLG/AUTOSPC/0 $
60  COND    LBL4,GPSPFLG $
61  GPSP    GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
62  OFP     OGPST,,,,,//S,N,CARDNO $
63  LABEL   LBL4 $
64  EQUIV   KGG,KNN/MPCF1/MGG,MNN/MPCF1/ BGG,BNN/MPCF1/K4GG,K4NN/MPCF1 $
65  COND    LBL2,MPCF1 $
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 66  MCE1     USET,RG/GM $
 67  MCE2     USET,GM,KGG,MGG,BGG,K4GG/KNN,MNN,BNN,K4NN $
 68  LABEL    LBL2 $
 69  EQUIV    KNN,KFF/SINGLE/MNN,MFF/SINGLE/BNN,BFF/SINGLE/K4NN,K4FF/SINGLE $
 70  COND     LBL3,SINGLE $
 71  SCE1     USET,KNN,MNN,BNN,K4NN/KFF,KFS,,MFF,BFF,K4FF $
 72  LABEL    LBL3 $
 73  EQUIV    KFF,KAA/OMIT/ MFF,MAA/OMIT/BFF,BAA/OMIT/K4FF,K4AA/OMIT $
 74  COND     LBL5,OMIT $
 75  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
 76  COND     LBLM,NOMGG $
 77  SMP2     USET,GO,MFF/MAA $
 78  LABEL    LBLM $
 79  COND     LBLB,NOBGG $
 80  SMP2     USET,GO,BFF/BAA $
 81  LABEL    LBLB $
 82  COND     LBL5,NOK4GG $
 83  SMP2     USET,GO,K4FF/K4AA $
 84  LABEL    LBL5 $
 85  DPD      DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPOOL,,,,,EED,EQDYN/
              LUSET/S,N,LUSETD/NOTFL/NODLT/NOPSDL/NOFRL/  NONLFT/NOTRL/S,N,
              NOEED/123/S,N,NOUE $
 86  COND     ERROR1,NOEED $
 87  EQUIV    GO,GOD/NOUE/GM,GMD/NOUE $
 88  PARAM    //*ADD*/NEVER/1/0 $
 89  PARAM    //*MPY*/REPEATE/1/-1 $
 90  BMG      MATPOOL,BGPDT,EQEXIN,CSTM/BDPOOL/S,N,NOKBFL/S,N,NOABFL/ S,N,
              MFACT $
 91  PARAM    //*AND*/NOFL/NOABFL/NOKBFL $
 92  PURGE    KBFL/NOKBFL/ ABFL/NOABFL $
 93  COND     LBL13,NOFL $
 94  MTRXIN,  ,BDPOOL,EQDYN,,/ABFL,KBFL,/LUSETD/S,N,NOABFL/S,N,NOKBFL/0 $
 95  LABEL    LBL13 $                     Top of Direct Input Matrix Loop
 96  PURGE    PHID,CLAMA,OPHID,OQPC1,OCPHIP,OESC1,OEFC1,CPHIP,QPC,   K2PP,
              M2PP,B2PP,K2DD,M2DD,B2DD/NEVER $
 97  CASE     CASECC,/CASEXX/*CEIGN*/S,N,REPEATE/S,N,NOLOOP $
 98  MTRXIN   CASEXX,MATPOOL,EQDYN,,TFPOOL/K2DPP,M2DPP,B2PP/LUSETD/S,N,
              NOK2DPP/S,N,NOM2DPP/S,N,NOB2PP $
 99  PARAM    //*AND*/NOM2PP/NOABFL/NOM2DPP $
100  PARAM    //*AND*/NOK2PP/NOFL /NOK2DPP $
101  EQUIV    K2DPP,K2PP/NOFL/M2DPP,M2PP/NOABFL $
```


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RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 7

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
102  COND     LBLFL2,NOFL $
103  ADD5     ABFL,KBFL,K2DPP,,/K2PP/(-1.0,0.0) $
104  COND     LBLFL2,NOABFL $
105  TRNSP    ABFL/ABFLT $
106  ADD      ABFLT,M2DPP/M2PP/MFACT $
107  LABEL    LBLFL2 $
108  PARAM    //*AND*/BDEBA/NOUE/NOB2PP $
109  PARAM    //*AND*/MDEMA/NOUE/NOM2PP $
110  PARAM    //*AND*/KDEK2/NOGENL/NOSIMP $
111  PURGE    K2DD/NOK2PP/M2DD/NOM2PP/B2DD/NOB2PP $
112  EQUIV    M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA/MAA,MDD/MDEMA/BAA,
              BDD/BDEBA $
113  COND     LBL18,NOGPDT $
114  GKAD     USETD,GM,GO,KAA,BAA,MAA,K4AA,K2PP,M2PP,B2PP/KDD,BDD,MDD,GMD,
              GOD,K2DD,M2DD,B2DD/*CMPLEV*/*DISP*/*DIRECT*/C,Y,G=0.0/ 0.0/
              0.0/NOK2PP/NOM2PP/NOB2PP/   MPCF1/SINGLE/OMIT/NOUE/NOK4GG/
              NOBGG/KDEK2/-1 $
115  LABEL    LBL18 $
116  EQUIV    B2DD,BDD/NOBGG/ M2DD,MDD/NOSIMP/ K2DD,KDD/KDEK2 $
117  CEAD     KDD,BDD,MDD,EED,CASEXX/PHID,CLAMA,OCEIGS,/S,N,EIGVS $
118  OFP      OCEIGS,CLAMA,,,,//S,N,CARDNO $
119  COND     LBL16,EIGVS $
120  VDR      CASEXX,EQDYN,USETD,PHID,CLAMA,,/OPHID,/*CEIGN*/*DIRECT*/0/S,N,
              NOD/S,N,NOP/0 $
121  COND     LBL15,NOD $
122  OFP      OPHID,,,,,//S,N,CARDNO $
123  LABEL    LBL15 $
124  COND     LBL16,NOP $
125  EQUIV    PHID,CPHIP/NOA $
126  COND     LBL17,NOA $
127  SDR1     USETD,, PHID,,,GOD,GMD,,KFS,,/CPHIP,,QPC/1/*DYNAMICS* $
128  LABEL    LBL17 $
129  SDR2     CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,,CLAMA,QPC,CPHIP,EST,,/,OQPC1,
              OCPHIP,OESC1,OEFC1,/*CEIG* $
130  OFP      OCPHIP,OQPC1,OEFC1,OESC1,,//S,N,CARDNO $
131  LABEL    LBL16 $
132  COND     FINIS,REPEATE $
133  REPT     LBL13,100 $
                                  Bottom of Direct Input Matrix Loop
134  PRTPARM  //-2/*DIRCEAD* $
135  JUMP     FINIS $
```

RIGID FORMAT DMAP LISTING
RELEASE APR. 1984

DISPLACEMENT APPROACH, RIGID FORMAT 7

```
     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

136  LABEL    ERROR1 $
137  PRTPARM  //-1/*DIRCEAD* $
138  LABEL    ERROR3 $
139  PRTPARM  //-3/*DIRCEAD* $
140  LABEL    FINIS $
141  PURGE    DUMMY/MINUS1 $
142  END      $
```

3.8.2 Description of DMAP Operations for Direct Complex Eigenvalue Analysis

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

8. Go to DMAP No. 84 if there is only Direct Matrix Input.

9. GP2 generates Element Connection Table with internal indices.

12. Go to DMAP No. 20 if there are no structure plot requests.

13. PLTSET transforms user input into a form used to drive the structure plotter.

14. PRTMSG prints error messages associated with the structure plotter.

17. Go to DMAP No. 20 if no undeformed structure plots are requested.

18. PLØT generates all requested undeformed structure plots.

19. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

21. GP3 generates Grid Point Temperature Table.

22. TA1 generates element tables for use in matrix assembly and stress recovery.

24. Go to DMAP No. 49 if there are no structural elements.

29. EMG generates structural element stiffness, mass and damping matrix tables and dictionaries for later assembly by the EMA module.

31. Go to DMAP No. 33 if no stiffness matrix is to be assembled.

32. EMA assembles stiffness matrix $[K_{gg}^x]$ and Grid Point Singularity Table.

34. Go to DMAP No. 36 if no mass matrix is to be assembled.

35. EMA assembles mass matrix $[M_{gg}]$.

37. Go to DMAP No. 39 if no viscous damping matrix is to be assembled.

38. EMA assembles viscous damping matrix $[B_{gg}]$.

40. Go to DMAP No. 42 if no structural damping matrix is to be assembled.

41. EMA assembles structural damping matrix $[K_{gg}^4]$.

45. Go to DMAP No. 49 if no weight and balance information is requested.

46. Go to DMAP No. 138 and print Error Message No. 3 if no mass matrix exists.

47. GPWG generates weight and balance information.

48. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

50. Equivalence $[K_{gg}^x]$ to $[K_{gg}]$ if there are no general elements.

51. Go to DMAP No. 53 if there are no general elements.

52. SMA3 adds general elements to $[K_{gg}^x]$ to obtain stiffness matrix $[K_{gg}]$.

55. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations $[R_g]\{u_g\} = 0$.

57. Go to DMAP No. 63 if general elements are present.

58. Go to DMAP No. 63 if there are no structural elements.

60. Go to DMAP No. 63 if no potential grid point singularities exist.

61. GPSP generates a table of potential grid point singularities.

62. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

64. Equivalence $[K_{gg}]$ to $[K_{nn}]$, $[M_{gg}]$ to $[M_{nn}]$, $[B_{gg}]$ to $[B_{nn}]$ and $[K^4_{gg}]$ to $[K^4_{nn}]$ if no multipoint constraints exist.

65. Go to DMAP No. 68 if no multipoint constraints exist.

66. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

67. MCE2 partitions stiffness, mass and damping matrices

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right] , \qquad [M_{gg}] = \left[\begin{array}{c|c} \bar{M}_{nn} & M_{nm} \\ \hline M_{mn} & M_{mm} \end{array}\right]$$

$$[B_{gg}] = \left[\begin{array}{c|c} \bar{B}_{nn} & B_{nm} \\ \hline B_{mn} & B_{mm} \end{array}\right] \quad \text{and} \quad [K^4_{gg}] = \left[\begin{array}{c|c} \bar{K}^4_{nn} & K^4_{nm} \\ \hline K^4_{mn} & K^4_{mm} \end{array}\right]$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] ,$$

$$[M_{nn}] = [\bar{M}_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m] ,$$

$$[B_{nn}] = [\bar{B}_{nn}] + [G_m^T][B_{mn}] + [B_{mn}^T][G_m] + [G_m^T][B_{mm}][G_m] ,$$

$$[K^4_{nn}] = [\bar{K}^4_{nn}] + [G_m^T][K^4_{mn}] + [K^4_{mn}]^T[G_m] + [G_m^T][K^4_{mm}][G_m] .$$

69. Equivalence $[K_{nn}]$ to $[K_{ff}]$, $[M_{nn}]$ to $[M_{ff}]$, $[B_{nn}]$ to $[B_{ff}]$ and $[K^4_{nn}]$ to $[K^4_{ff}]$ if no single-point constraints exist.

70. Go to DMAP No. 72 if no single-point constraints exist.

71. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right], \qquad [M_{nn}] = \left[\begin{array}{c|c} M_{ff} & M_{fs} \\ \hline M_{sf} & M_{ss} \end{array}\right],$$

$$[B_{nn}] = \left[\begin{array}{c|c} B_{ff} & B_{fs} \\ \hline B_{sf} & B_{ss} \end{array}\right] \text{ and } \qquad [K^4_{nn}] = \left[\begin{array}{c|c} K^4_{ff} & K^4_{fs} \\ \hline K^4_{sf} & K^4_{ss} \end{array}\right].$$

73. Equivalence $[K_{ff}]$ to $[K_{aa}]$, $[M_{ff}]$ to $[M_{aa}]$, $[B_{ff}]$ to $[B_{aa}]$ and $[K_{ff}]^4$ to $[K^4_{aa}]$ if no omitted coordinates exist.

74. Go to DMAP No. 84 if no omitted coordinates exist.

75. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right],$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{ao}][G_o]$.

76. Go to DMAP No. 78 if no mass matrix exists.

77. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \left[\begin{array}{c|c} \bar{M}_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right],$$

and performs matrix reduction

$$[M_{aa}] = [\bar{M}_{aa}] + [M_{ao}][G_o] + [M_{ao}G_o]^T + [G_o^T][M_{oo}][G_o]$$

79. Go to DMAP No. 84 if no viscous damping matrix exists.

80. SMP2 partitions constrained viscous damping matrix

$$[B_{ff}] = \left[\begin{array}{c|c} \bar{B}_{aa} & B_{ao} \\ \hline B_{oa} & B_{oo} \end{array}\right],$$

and performs matrix reduction

$$[B_{aa}] = [\bar{B}_{aa}] + [B_{ao}][G_o] + [B_{ao}G_o]^T + [G_o^T][B_{oo}][G_o] \quad .$$

82. Go to DMAP No. 84 if no structural damping matrix exists.

83. SMP2 partitions constrained structural damping matrix

$$[K_{ff}^4] = \left[\begin{array}{c|c} \bar{K}_{aa}^4 & K_{ao}^4 \\ \hline K_{oa}^4 & K_{oo}^4 \end{array}\right] ,$$

and performs matrix reduction

$$[K_{aa}^4] = [\bar{K}_{aa}^4] + [K_{ao}^4][G_o] + [K_{ao}^4 G_o]^T + [G_o^T][K_{oo}^4][G_o]$$

85. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating the internal and external grid point numbers (GPLD), including extra points introduced for dynamic analysis (SILD), and prepares Transfer Function Pool (TFPØØL), and Eigenvalue Extraction Data (EED).

86. Go to DMAP No. 136 and print Error Message No. 1 if there is no Eigenvalue Extraction Data.

87. Equivalence $[G_o]$ to $[G_o^d]$ and $[G_m]$ to $[G_m^d]$ if there are no extra points introduced for dynamic analysis.

90. BMG generates DMIG card images describing the interconnection of the fluid and the structure.

93. Go to DMAP No. 95 if no fluid-structure interface is defined.

94. MTRXIN generates fluid boundary matrices $[A_{b,f\ell}]$ and $[K_{b,f\ell}]$. The matrix $[K_{b,f\ell}]$ is generated only for a nonzero gravity in the fluid.

95. Beginning of loop for additional sets of direct input matrices.

97. CASE extracts the appropriate record from CASECC corresponding to the current loop and copies it into CASEXX.

98. MTRXIN selects the direct input matrices $[K_{pp}^{2d}]$, $[M_{pp}^{2d}]$ and $[B_{pp}^2]$ for the current loop.

101. Equivalence $[K_{pp}^2]$ to $[K_{pp}^{2d}]$ if no fluid-structure interface is defined and equivalence $[M_{pp}^2]$ to $[M_{pp}^{2d}]$ if there is no $[A_{b,f\ell}]$.

102. Go to DMAP No. 107 if no fluid-structure interface is defined.

103. ADD5 adds $[K_{b,f\ell}]$ and $[K_{pp}^{2d}]$ and subtracts $[A_{b,f\ell}]$ from them to form $[K_{pp}^2]$.

104. Go to DMAP No. 107 if there is no $[A_{b,f\ell}]$.

105. Transpose $[A_{b,f\ell}]$ to obtain $[A_{b,f\ell}]^T$.

106. ADD assembles input matrix $[M_{pp}^2]$ = MFACT $[A_{b,f\ell}]^T + [M_{pp}^{2d}]$.

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112. Equivalence $[M^2_{pp}]$ to $[M^2_{dd}]$, $[B^2_{pp}]$ to $[B^2_{dd}]$ and $[K^2_{pp}]$ to $[K^2_{dd}]$ if no constraints are applied, $[M_{aa}]$ to $[M_{dd}]$ if there are no direct input mass matrices and no extra points, and $[B_{aa}]$ to $[B_{dd}]$ if there are no direct input damping matrices and no extra points.

113. Go to DMAP No. 115 if only extra points are defined.

114. GKAD assembles stiffness, mass and damping matrices for use in Direct Complex Eigenvalue Analysis

$$[K_{dd}] = (1 + ig)[K^1_{dd}] + [K^2_{dd}] + i[K^4_{dd}] \ ,$$

$$[M_{dd}] = [M^1_{dd}] + [M^2_{dd}] \quad \text{and}$$

$$[B_{dd}] = [B^1_{dd}] + [B^2_{dd}] \ .$$

Direct input matrices may be complex.

116. Equivalence $[K^2_{dd}]$ to $[K_{dd}]$ if all stiffness is Direct Matrix Input, $[M^2_{dd}]$ to $[M_{dd}]$ if all mass is Direct Matrix Input and $[B^2_{dd}]$ to $[B_{dd}]$ is all damping is Direct Matrix Input.

117. CEAD extracts complex eigenvalues and eigenvectors from the equation

$$[M_{dd}p^2 + B_{dd}p + K_{dd}]\{u_d\} = 0$$

and normalizes eigenvectors according to one of the following user requests:

1) Unit magnitude of a selected component
2) Unit magnitude of the largest component.

118. ØFP formats the summary of complex eigenvalues (CLAMA) and summary of eigenvalue extraction information (ØCEIGS) prepared by CEAD and places them on the system output file for printing.

119. Go to DMAP No. 131 if no eigenvalues were found.

120. VDR prepares eigenvectors for output, using only the independent degrees of freedom.

121. Go to DMAP No. 123 if there is no output request for independent degrees of freedom.

122. ØFP formats the eigenvectors for independent degrees of freedom prepared by VDR and places them on the system output file for printing.

124. Go to DMAP No. 131 if there is no output request involving dependent degrees of freedom or forces and stresses.

125. Equivalence $\{\phi_d\}$ to $\{\phi_p\}$ if no constraints are applied.

126. Go to DMAP No. 128 if no constraints are applied.

127. SDR1 recovers dependent components of eigenvectors

$$\{\phi_o\} = [G_o^d]\{\phi_d\} \quad , \qquad \left\{\frac{\phi_d}{\phi_o}\right\} = \{\phi_f + \phi_e\} \quad ,$$

$$\left\{\frac{\phi_f + \phi_e}{\phi_s}\right\} = \{\phi_n + \phi_e\} \quad , \qquad \{\phi_m\} = [G_m^d]\{\phi_n + \phi_e\} \quad ,$$

$$\left\{\frac{\phi_n + \phi_e}{\phi_m}\right\} = \{\phi_p\}$$

and recovers single-point forces of constraint $\{q_s\} = [K_{fs}^T]\{\phi_f\}$.

129. SDR2 calculates element forces (ØEFC1) and stresses (ØESC1) and prepares eigenvectors (ØCPHIP) and single-point forces of constraint (ØQPC1) for output.

130. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

132. Go to DMAP No. 140 if no additional sets of direct input matrices need to be processed.

133. Go to DMAP No. 95 if additional sets of direct input matrices need to be processed.

134. Print Error Message No. 2 and terminate execution.

135. Go to DMAP No. 140 and make normal exit.

137. Print Error Message No. 1 and terminate execution.

139. Print Error Message No. 3 and terminate execution.

3.8.3 Output for Direct Complex Eigenvalue Analysis

Each complex eigenvalue is identified with a root number determined by sorting the complex eigenvalues according to the magnitude of the imaginary part, with positive values considered as a group ahead of all negative values. The following summary of the complex eigenvalues extracted is automatically printed for each set of direct input matrices:

1. Root Number
2. Extraction Order
3. Real and Imaginary Parts of the Eigenvalue
4. The coefficients f_j (frequency) and g_j (damping coefficient) in the following representation of the eigenvalue

$$P_j = 2\pi f_j(i - \frac{1}{2} g_j)$$

The following summary of the eigenvalue analysis performed, using the Determinant method, is automatically printed for each set of direct input matrices:

1. Number of eigenvalues extracted
2. Number of passes through starting points.
3. Number of criteria changes.
4. Number of starting point moves.
5. Number of triangular decompositions.
6. Number of failures to iterate to a root.
7. Number of predictions outside region.
8. Reason for termination:
   (1) The number of roots desired have been found.
   (2) All predictions for eigenvalues are outside the regions specified.
   (3) Insufficient time to find another root.
   (4) Matrix is singular at first three starting points.
9. Swept determinant functions for each starting point.

The following summary of the eigenvalue analysis performed, using the Inverse Power method, is automatically printed for each region specified:

1. Number of eigenvalues extracted.
2. Number of starting points used.
3. Number of starting point moves.
4. Number of triangular decompositions.

5. Number of vector iterations.
6. Reason for termination.
   (1) Two consecutive singularities encountered while performing triangular decomposition.
   (2) Four starting point moves while tracking a single root.
   (3) All eigenvalues found in the region specified.
   (4) Three times the number of roots estimated in the region have been extracted.
   (5) All eigenvalues that exist in the problem have been found.
   (6) The number of roots desired have been found.
   (7) One or more eigenvalues have been found outside the region specified.
   (8) Insufficient time to find another root.
   (9) Unable to converge.

The following summary of the eigenvalue analysis performed, using the complex Tridiagonal Reduction (FEER) method, is automatically printed:

1. Number of eigenvalues extracted.
2. Number of starting points used.
   This corresponds to the total number of random starting and restart vectors used by the complex FEER process for all neighborhoods.
3. Number of starting point moves.
   Not used in FEER (set equal to zero).
4. Number of triangular decompositions.
   Always equal to the number of points of interest (neighborhoods) in the complex plane processed by FEER, since ordinarily only one triangular decomposition is required by FEER for each point of interest, unless the dynamic matrix is singular at a given point of interest, in which case an additional decomposition is required (obtained by moving the point of interest slightly).
5. Total number of vector iterations.
   The total number of reorthogonalizations of all the trial vectors employed.
6. Reason for termination.
   (0) All, or more solutions than the number requested by the user, have been determined (normal termination).

(1) All neighborhoods have been processed, but FEER has not obtained the desired number of roots in each neighborhood, possibly because they have already been found in other neighborhoods.

(2) Abnormal termination - either no roots found or none passes the FEER error test.

The following printed output, sorted by complex eigenvalue root number (SØRT1), may be requested for any complex eigenvalue extracted, as either real and imaginary parts or magnitude and phase angle (0° - 360° lead):

1. The eigenvector for a list of PHYSICAL points (grid points and extra scalar points introduced for dynamic analysis) or SØLUTIØN points (points used in the formulation of the dynamic equation).
2. Nonzero components of the single-point forces of constraint for a list of PHYSICAL points.
3. Stresses and forces in selected elements.

In addition, an undeformed plot of the structural model may be requested.

3.8.4 Case Control Deck for Direct Complex Eigenvalue Analysis

The following items relate to subcase definition and data selection for Direct Complex Eigenvalue Analysis:

1. At least one subcase must be defined for each unique set of direct input matrices (K2PP, M2PP, B2PP).
2. Multiple subcases for each set of direct input matrices are used only to control output requests. A single subcase for each set of direct input matrices is sufficient if the same output is desired for all modes. If consecutive multiple subcases are present for a single set of direct input matrices, the output requests will be honored in succession for increasing mode numbers. MØDES may be used to repeat subcases in order to make the same output request for several consecutive modes.
3. CMETHØD must be used to select an EIGC card from the Bulk Data Deck for each set of direct input matrices.
4. On restart following an unscheduled exit due to insufficient time, the subcase structure must be changed to reflect the sets of direct input matrices that were completed, and either CMETHØD must be changed to select an EIGC card that reflects any complex eigenvalues found in the previous execution or EIGP cards must be used to insert poles

for previously found eigenvalues. Otherwise, the previously found eigenvalues will be extracted again.

5. Constraints must be defined above the subcase level.

3.8.5 Parameters for Direct Complex Eigenvalue Analysis

The following parameters are used in Direct Complex Eigenvalue Analysis:

1. GRDPNT - optional. A positive integer value of this parameter will cause the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.

2. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in EMA. Not recommended for use in hydroelastic problems.

3. G - optional. The real value of this parameter is used as a uniform structural damping coefficient in the direct formulation of dynamics problems. Not recommended for use in hydroelastic problems.

4. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters will cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.

5. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.

6. AUTØSPC - reserved for future optional use. The default value is -1.

3.8.6 Rigid Format Error Messages from Direct Complex Eigenvalue Analysis

The following fatal errors are detected by the DMAP statements in the Direct Complex Eigenvalue Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

DIRECT CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 1 - EIGENVALUE EXTRACTIØN DATA REQUIRED FØR CØMPLEX EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGC card in the Bulk Data Deck and CMETHØD in the Case Control Deck must select an EIGC set.

DIRECT CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 2 - ATTEMPT TØ EXECUTE MØRE THAN 100 LØØPS.

An attempt has been made to use more than 100 sets of direct input matrices. This number may be increased by ALTERing the REPT instruction following SDR2.

DIRECT CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 3 - MASS MATRIX REQUIRED FØR WEIGHT AND BALANCE CALCULATIØNS.

The mass matrix is null because either no elements were defined on Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

3.9 DIRECT FREQUENCY AND RANDOM RESPONSE

3.9.1 DMAP Sequence for Direct Frequency and Random Response

RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 8

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OPTIONS IN EFFECT GO ERR=2 LIST NODECK NOREF NOOSCAR

```
 1 BEGIN    DISP 08 - DIRECT FREQUENCY/RANDOM RESPONSE ANALYSIS-APR. 1984 $
 2 PRECHK   ALL $
 3 FILE     KGGX=TAPE/KGG=TAPE/GOD=SAVE/GMD=SAVE/MDD=SAVE/BDD=SAVE $
 4 PARAM    //*MPY*/CARDNO/0/0 $
 5 GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  S,N,
            NOGPDT/ALWAYS=-1 $
 6 PLTTRAN  BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $
 7 PURGE    USET,GM,GO,KAA,BAA,MAA,K4AA,KFS,PSF,QPC,EST,ECT,PLTSETX,PLTPAR,
            GPSETS,ELSETS/NOGPDT $
 8 COND     LBL5,NOGPDT $
 9 GP2      GEOM2,EQEXIN/ECT $
10 PARAML   PCDB//*PRES*////JUMPPLOT $
11 PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $
12 COND     P1,JUMPPLOT $
13 PLTSET   PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/S,N,
            JUMPPLOT=-1 $
14 PRTMSG   PLTSETX// $
15 PARAM    //*MPY*/PLTFLG/1/1 $
16 PARAM    //*MPY*/PFILE/0/0 $
17 COND     P1,JUMPPLOT $
18 PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
            NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $
19 PRTMSG   PLOTX1//S
20 LABEL    P1 $
21 GP3      GEOM3,EQEXIN,GEOM2/,GPTT/NOGRAVS
22 TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/LUSET/S,N,NOSIMP=
            -1/1/S,N,NOGENL=-1/S,N,GENEL $
23 PURGE    K4GG,GPST,OGPST,MGG,BGG,K4NN,K4FF,K4AA,MNN,MFF,MAA,BNN,BFF,BAA,
            KGGX/NOSIMP/OGPST/GENEL $
24 COND     LBL1,NOSIMP $
25 PARAM    //*ADD*/NOKGGX/1/0 $
26 PARAM    //*ADD*/NOMGG/1/0 $
27 PARAM    //*ADD*/NOBGG=-1/1/0 $
28 PARAM    //*ADD*/NOK4GG/1/0 $
29 EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,BELM,BDICT/    S,
            N,NOKGGX/S,N,NOMGG/S,N,NOBGG/S,N,NOK4GG//C,Y,COUPMASS/C,Y,
            CPBAR/C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,
```

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```
             CPTRIA2/C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC $
 30  PURGE   GPST/NOKGGX/MGG/NOMGG $
 31  COND    LBLKGGX,NOKGGX $
 32  EMA     GPECT,KDICT,KELM/KGGX,GPST $
 33  LABEL   LBLKGGX $
 34  COND    LBLMGG,NOMGG $
 35  EMA     GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $
 36  LABEL   LBLMGG $
 37  COND    LBLBGG,NOBGG $
 38  EMA     GPECT,BDICT,BELM/BGG, $
 39  LABEL   LBLBGG $
 40  COND    LBLK4GG,NOK4GG $
 41  EMA     GPECT,KDICT,KELM/K4GG,/NOK4GG $
 42  LABEL   LBLK4GG $
 43  PURGE   MNN,MFF,MAA/NOMGG $
 44  PURGE   BNN,BFF,BAA/NOBGG $
 45  COND    LBL1,GRDPNT $
 46  COND    ERROR4,NOMGG $
 47  GPWG    BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $
 48  OFP     OGPWG,,,,,//S,N,CARDNO $
 49  LABEL   LBL1 $
 50  EQUIV   KGGX,KGG/NOGENL $
 51  COND    LBL11,NOGENL $
 52  SMA3    GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $
 53  LABEL   LBL11 $
 54  PARAM   //*MPY*/NSKIP/0/0 $
 55  GP4     CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,USET,ASET/ LUSET/
             S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/S,N,NSKIP/S,
             N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/ S,Y,AUTOSPC $
 56  PURGE   GM,GMD/MPCF1/GO,GOD/OMIT/KFS,PSF,QPC/SINGLE $
 57  COND    LBL4,GENEL $
 58  COND    LBL4,NOSIMP $
 59  PARAM   //*EQ*/GPSPFLG/AUTOSPC/0 $
 60  COND    LBL4,GPSPFLG $
 61  GPSP    GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
 62  OFP     OGPST,,,,,//S,N,CARDNO $
 63  LABEL   LBL4 $
 64  EQUIV   KGG,KNN/MPCF1/MGG,MNN/MPCF1/ BGG,BNN/MPCF1/K4GG,K4NN/MPCF1 $
```

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```
65  COND     LBL2,MPCF1 $
66  MCE1     USET,RG/GM $
67  MCE2     USET,GM,KGG,MGG,BGG,K4GG/KNN,MNN,BNN,K4NN $
68  LABEL    LBL2 $
69  EQUIV    KNN,KFF/SINGLE/MNN,MFF/SINGLE/BNN,BFF/SINGLE/K4NN,K4FF/SINGLE $
70  COND     LBL3,SINGLE $
71  SCE1     USET,KNN,MNN,BNN,K4NN/KFF,KFS,,MFF,BFF,K4FF $
72  LABEL    LBL3 $
73  EQUIV    KFF,KAA/OMIT $
74  EQUIV    MFF,MAA/OMIT $
75  EQUIV    BFF,BAA/OMIT $
76  EQUIV    K4FF,K4AA/OMIT $
77  COND     LBL5,OMIT $
78  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
79  COND     LBLM,NOMGG $
80  SMP2     USET,GO,MFF/MAA $
81  LABEL    LBLM $
82  COND     LBLB,NOBGG $
83  SMP2     USET,GO,BFF/BAA $
84  LABEL    LBLB $
85  COND     LBL5,NOK4GG $
86  SMP2     USET,GO,K4FF/K4AA $
87  LABEL    LBL5 $
88  DPD      DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPOOL,DLT,PSDL,FRL,,,,
             EQDYN/LUSET/S,N,LUSETD/NOTFL/S,N,NODLT/S,N,NOPSDL/S,N,  NOFRL/
             NONLFT/NOTRL/NOEED//S,N,NOUE $
89  EQUIV    GO,GOD/NOUE/GM,GMD/NOUE $
90  PARAM    //*ADD*/NEVER/1/0 $
91  PARAM    //*MPY*/REPEATF/-1/1 $
92  BMG      MATPOOL,BGPDT,EQEXIN,CSTM/BDPOOL/S,N,NOKBFL/S,N,NOABFL/ S,N,
             MFACT $
93  PARAM    //*AND*/NOFL/NOABFL/NOKBFL $
94  PURGE    KBFL/NOKBFL/ ABFL/NOABFL $
95  COND     LBL13,NOFL $
96  MTRXIN,  ,BDPOOL,EQDYN,,/ABFL,KBFL,/LUSETD/S,N,NOABFL/S,N,NOKBFL/0 $
97  LABEL    LBL13 $                         Top of Direct Input Matrix Loop
98  PURGE    OUDVC1,OUDVC2,XYPLTFA,OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,OPPC2,
             OQPC2,OUPVC2,OESC2,OEFC2,XYPLTF,PSDF,AUTO,XYPLTR,    K2PP,M2PP,
             B2PP,K2DD,M2DD,B2DD/NEVER $
```


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```
 99  CASE     CASECC,PSDL/CASEXX/*FREQ*/S,N,REPEATF/S,N,NOLOOP $
100  MTRXIN   CASEXX,MATPOOL,EQDYN,,TFPOOL/K2DPP,M2DPP,B2PP/LUSETD/S,N,
              NOK2DPP/S,N,NOM2DPP/S,N,NOB2PP $
101  PARAM    //*AND*/NOM2PP/NOABFL/NOM2DPP $
102  PARAM    //*AND*/NOK2PP/NOFL /NOK2DPP $
103  EQUIV    K2DPP,K2PP/NOFL/M2DPP,M2PP/NOABFL $
104  COND     LBLFL2,NOFL $
105  ADD5     ABFL,KBFL,K2DPP,,/K2PP/(-1.0,0.0) $
106  COND     LBLFL2,NOABFL $
107  TRNSP    ABFL/ABFLT $
108  ADD      ABFLT,M2DPP/M2PP/MFACT $
109  LABEL    LBLFL2 $
110  PARAM    //*AND*/BDEBA/NOUE/NOB2PP $
111  PARAM    //*AND*/KDEK2/NOGENL/NOSIMP $
112  PARAM    //*AND*/MDEMA/NOUE/NOM2PP $
113  PURGE    K2DD/NOK2PP/M2DD/NOM2PP/B2DD/NOB2PP $
114  EQUIV    M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA/MAA,MDD/MDEMA/BAA,
              BDD/BDEBA $
115  COND     LBL18,NOGPDT $
116  GKAD     USETD,GM,GO,KAA,BAA,MAA,K4AA,K2PP,M2PP,B2PP/KDD,BDD,MDD,GMD,
              GOD,K2DD,M2DD,B2DD/*FREQRESP*/*DISP*/*DIRECT*/C,Y,G=0.0/0.0/
              0.0/NOK2PP/NOM2PP/NOB2PP/   MPCF1/SINGLE/OMIT/NOUE/NOK4GG/
              NOBGG/KDEK2/-1 $
117  LABEL    LBL18 $
118  EQUIV    B2DD,BDD/NOBGG/ M2DD,MDD/NOSIMP/ K2DD,KDD/KDEK2 $
119  COND     ERROR1,NOFRL $
120  COND     ERROR2,NODLT $
121  FRRD     CASEXX,USETD,DLT,FRL,GMD,GOD,KDD,BDD,MDD,,DIT/UDVF,PSF,PDF,PPF/
              *DISP*/*DIRECT*/LUSETD/MPCF1/SINGLE/OMIT/   NONCUP/FRQSET $
122  EQUIV    PPF,PDF/NOSET $
123  VDR      CASEXX,EQDYN,USETD,UDVF,PPF,XYCDB,/OUDVC1,/*FREQRESP*/  *
              DIRECT*/S,N,NOSORT2/S,N,NOD/S,N,NOP/0 $
124  COND     LBL15,NOD $
125  COND     LBL15A,NOSORT2 $
126  SDR3     OUDVC1,,,,,/OUDVC2,,,,, $
127  OFP      OUDVC2,,,,,//S,N,CARDNO $
128  XYTRAN   XYCDB,OUDVC2,,,,/XYPLTFA/*FREQ*/*DSET*/S,N,PFILE/S,N,CARDNO $
129  XYPLOT   XYPLTFA// $
130  JUMP     LBL15 $
131  LABEL    LBL15A $
132  OFP      OUDVC1,,,,,//S,N,CARDNO $
```

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    LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

133  LABEL    LBL15 $
134  COND     LBL20,NOP $
135  EQUIV    UDVF,UPVC/NOA $
136  COND     LBL19,NOA $
137  SDR1     USETD,,UDVF,,,GOD,GMD,PSF,KFS,,/UPVC,,QPC/1/*DYNAMICS* $
138  LABEL    LBL19 $
139  SDR2     CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,BGPDP,PPF,QPC,UPVC,EST,XYCDB,
              PPF/OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,PUPVC1/*FREQRESP*/   S,N,
              NOSORT2 $
140  COND     LBL17,NOSORT2 $
141  SDR3     OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,/OPPC2,OQPC2,OUPVC2,OESC2,
              OEFC2, $
142  OFP      OPPC2,OQPC2,OUPVC2,OEFC2,OESC2,//S,N,CARDNO $
143  XYTRAN   XYCDB,OPPC2,OQPC2,OUPVC2,OESC2,OEFC2/XYPLTF/*FREQ*/*PSET*/   S,
              N,PFILE/S,N,CARDNO $
144  XYPLOT   XYPLTF// $
145  COND     LBL16,NOPSDL $
146  RANDOM   XYCDB,DIT,PSDL,OUPVC2,OPPC2,OQPC2,OESC2,OEFC2,CASEXX/PSDF,AUTO/
              S,N,NORD $
147  COND     LBL16,NORD $
148  XYTRAN   XYCDB,PSDF,AUTO,,,/XYPLTR/*RAND*/*PSET*/S,N,PFILE/   S,N,
              CARDNO $
149  XYPLOT   XYPLTR// $
150  JUMP     LBL16 $
151  LABEL    LBL17 $
152  PURGE    PSDF/NOSORT2 $
153  OFP      OUPVC1,OPPC1,OQPC1,OEFC1,OESC1,//S,N,CARDNO $
154  LABEL    LBL16 $
155  PURGE    PSDF/NOPSDL $
156  COND     LBL20,JUMPPLOT $
157  PLOT     PLTPAR,GPSETS,ELSETS,CASEXX,BGPDT,EQEXIN,SIP,,PUPVC1,   GPECT,
              OESC1/PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/  S,N,PFILE $
158  PRTMSG   PLOTX2// $
159  LABEL    LBL20 $
160  COND     FINIS,REPEATF $                Bottom of Direct Input Matrix Loop
161  REPT     LBL13,100 $
162  PRTPARM  //-3/*DIRFRRD* $
163  JUMP     FINIS $
164  LABEL    ERROR2 $
165  PRTPARM  //-2/*DIRFRRD* $
```

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```
166  LABEL    ERROR1 $
167  PRTPARM  //-1/*DIRFRRD* $
168  LABEL    ERROR4 $
169  PRTPARM  //-4/*DIRFRRD* $
170  LABEL    FINIS $
171  PURGE    DUMMY/ALWAYS $
172  END      $
```

3.9.2 Description of DMAP Operations for Direct Frequency and Random Response

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

8. Go to DMAP No. 87 if there is only Direct Matrix Input.

9. GP2 generates Element Connection Table with internal indices.

12. Go to DMAP No. 20 if there are no structure plot requests.

13. PLTSET transforms user input into a form used to drive the structure plotter.

14. PRTMSG prints error messages associated with the structure plotter.

17. Go to DMAP No. 20 if no undeformed structure plots are requested.

18. PLØT generates all requested undeformed structure plots.

19. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

21. GP3 generates Grid Point Temperature Table.

22. TA1 generates element tables for use in matrix assembly and stress recovery.

24. Go to DMAP No. 49 if there are no structural elements.

29. EMG generates structural element stiffness, mass and damping matrix tables and dictionaries for later assembly by the EMA module.

31. Go to DMAP No. 33 if no stiffness matrix is to be assembled.

32. EMA assembles stiffness matrix $[K^x_{gg}]$ and Grid Point Singularity Table.

34. Go to DMAP No. 36 if no mass matrix is to be assembled.

35. EMA assembles mass matrix $[M_{gg}]$.

37. Go to DMAP No. 39 if no viscous damping matrix is to be assembled.

38. EMA assembles viscous damping matrix $[B_{gg}]$.

40. Go to DMAP No. 42 if no structural damping matrix is to be assembled.

41. EMA assembles structural damping matrix $[K^4_{gg}]$.

45. Go to DMAP No. 49 if no weight and balance information is requested.

46. Go to DMAP No. 168 and print Error Message No. 4 if no mass matrix exists.

47. GPWG generates weight and balance information.

48. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

50. Equivalence $[K^x_{gg}]$ to $[K_{gg}]$ if there are no general elements.

51. Go to DMAP No. 53 if there are no general elements.

52. SMA3 adds general elements to $[K^x_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

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55. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations $[R_g]\{u_g\} = 0$.

57. Go to DMAP No. 63 if general elements are present.

58. Go to DMAP No. 63 if there are no structural elements.

60. Go to DMAP No. 63 if no potential grid point singularities exist.

61. GPSP generates a table of potential grid point singularities.

62. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

64. Equivalence $[K_{gg}]$ to $[K_{nn}]$, $[M_{gg}]$ to $[M_{nn}]$, $[B_{gg}]$ to $[B_{nn}]$ and $[K^4_{gg}]$ to $[K^4_{nn}]$ if no multipoint constraints exist.

65. Go to DMAP No. 68 if no multipoint constraints exist.

66. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

67. MCE2 partitions stiffness, mass and damping matrices

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right] , \qquad [M_{gg}] = \left[\begin{array}{c|c} \bar{M}_{nn} & M_{nm} \\ \hline M_{mn} & M_{mm} \end{array}\right] ,$$

$$[B_{gg}] = \left[\begin{array}{c|c} \bar{B}_{nn} & B_{nm} \\ \hline B_{mn} & B_{mm} \end{array}\right] \quad \text{and} \quad [K^4_{gg}] = \left[\begin{array}{c|c} \bar{K}^4_{nn} & K^4_{nm} \\ \hline K^4_{mn} & K^4_{mm} \end{array}\right]$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] ,$$

$$[M_{nn}] = [\bar{M}_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m] ,$$

$$[B_{nn}] = [\bar{B}_{nn}] + [G_m^T][B_{mn}] + [B_{mn}^T][G_m] + [G_m^T][B_{mm}][G_m] ,$$

$$[K^4_{nn}] = [\bar{K}^4_{nn}] + [G_m^T][K^4_{mn}] + [K^4_{mn}]^T[G_m] + [G_m^T][K^4_{mm}][G_m] .$$

69. Equivalence $[K_{nn}]$ to $[K_{ff}]$, $[M_{nn}]$ to $[M_{ff}]$, $[B_{nn}]$ to $[B_{ff}]$ and $[K_{nn}]^4$ to $[K^4_{ff}]$ if no single-point constraints exist.

70. Go to DMAP No. 72 if no single-point constraints exist.

71. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right], \qquad [M_{nn}] = \left[\begin{array}{c|c} M_{ff} & M_{fs} \\ \hline M_{sf} & M_{ss} \end{array}\right],$$

$$[B_{nn}] = \left[\begin{array}{c|c} B_{ff} & B_{fs} \\ \hline B_{sf} & B_{ss} \end{array}\right] \text{ and } \qquad [K^4_{nn}] = \left[\begin{array}{c|c} K^4_{ff} & K^4_{fs} \\ \hline K^4_{sf} & K^4_{ss} \end{array}\right].$$

73. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

74. Equivalence $[M_{ff}]$ to $[M_{aa}]$ if no omitted coordinates exist.

75. Equivalence $[B_{ff}]$ to $[B_{aa}]$ if no omitted coordinates exist.

76. Equivalence $[K^4_{ff}]$ to $[K^4_{aa}]$ if no omitted coordinates exist.

77. Go to DMAP No. 87 if no omitted coordinates exist.

78. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right],$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{ao}][G_o]$.

79. Go to DMAP No. 81 if no mass matrix exists.

80. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \left[\begin{array}{c|c} \bar{M}_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right],$$

and performs matrix reduction

$$[M_{aa}] = [\bar{M}_{aa}] + [M_{ao}][G_o] + [M_{ao}G_o]^T + [G_o^T][M_{oo}][G_o]$$

82. Go to DMAP No. 84 if no viscous damping matrix exists.

83. SMP2 partitions constrained viscous damping matrix

$$[B_{ff}] = \left[\begin{array}{c|c} \bar{B}_{aa} & B_{ao} \\ \hline B_{oa} & B_{oo} \end{array}\right],$$

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and performs matrix reduction

$$[B_{aa}] = [\bar{B}_{aa}] + [B_{ao}][G_o] + [B_{ao}G_o]^T + [G_o^T][B_{oo}][G_o]$$

85. Go to DMAP No. 87 if no structural damping matrix exists.

86. SMP2 partitions constrained structural damping matrix

$$[K_{ff}^4] = \left[\begin{array}{c|c} \bar{K}_{aa}^4 & K_{ao}^4 \\ \hline K_{oa}^4 & K_{oo}^4 \end{array}\right]$$

and performs matrix reduction

$$[K_{aa}^4] = [\bar{K}_{aa}^4] + [K_{ao}^4][G_o] + [K_{ao}^4 G_o]^T + [G_o^T][K_{oo}^4][G_o] \quad .$$

88. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating the internal and external grid point numbers, including extra points introduced for dynamic analysis, and prepares Transfer Function Pool, Dynamics Load Table, Power Spectral Density List and Frequency Response List.

89. Equivalence $[G_o]$ to $[G_o^d]$ and $[G_m]$ to $[G_m^d]$ if there are no extra points introduced for dynamic analysis.

92. BMG generates DMIG card images describing the interconnection of the fluid and the structure.

95. Go to DMAP No. 97 if no fluid-structure interface is defined.

96. MTRXIN generates fluid boundary matrices $[A_{b,f\ell}]$ and $[K_{b,f\ell}]$. The matrix $[K_{b,f\ell}]$ is generated only for a nonzero gravity in the fluid.

97. Beginning of loop for additional sets of direct input matrices.

99. CASE extracts the appropriate record from CASECC corresponding to the current loop and copies it into CASEXX.

100. MTRXIN selects the direct input matrices $[K_{pp}^{2d}]$, $[M_{pp}^{2d}]$ and $[B_{pp}^2]$ for the current loop.

103. Equivalence $[K_{pp}^2]$ to $[K_{pp}^{2d}]$ if no fluid-structure interface is defined and equivalence $[M_{pp}^2]$ to $[M_{pp}^{2d}]$ if there is no $[A_{b,f\ell}]$.

104. Go to DMAP No. 109 if no fluid-structure interface is defined.

105. ADD5 adds $[K_{b,f\ell}]$ and $[K_{pp}^{2d}]$ and subtracts $[A_{b,f\ell}]$ from them to form $[K_{pp}^2]$.

106. Go to DMAP No. 109 if there is no $[A_{b,f\ell}]$.

107. Transpose $[A_{b,f\ell}]$ to obtain $[A_{b,f\ell}]^T$.

108. ADD assembles input matrix $[M_{pp}^2]$ = MFACT $[A_{b,f\ell}]^T + [M_{pp}^{2d}]$.

114. Equivalence $[M^2_{pp}]$ to $[M^2_{dd}]$, $[B^2_{pp}]$ to $[B^2_{dd}]$ and $[K^2_{pp}]$ to $[K^2_{dd}]$ if no constraints are applied, $[M_{aa}]$ to $[M_{dd}]$ if there are no direct input mass matrices and no extra points, and $[B_{aa}]$ to $[B_{dd}]$ if there are no direct input damping matrices and no extra points.

115. Go to DMAP No. 117 if only extra points are defined.

116. GKAD assembles stiffness, mass and damping matrices for use in Direct Frequency Response:

$$[K_{dd}] = (1 + ig)[K^1_{dd}] + [K^2_{dd}] + i[K^4_{dd}] ,$$

$$[M_{dd}] = [M^1_{dd}] + [M^2_{dd}] \quad \text{and}$$

$$[B_{dd}] = [B^1_{dd}] + [B^2_{dd}] .$$

Direct input matrices may be complex.

118. Equivalence $[K^2_{dd}]$ to $[K_{dd}]$ if all stiffness is Direct Matrix Input, $[M^2_{dd}]$ to $[M_{dd}]$ if all mass is Direct Matrix Input and $[B^2_{dd}]$ to $[B_{dd}]$ is all damping is Direct Matrix Input.

119. Go to DMAP No. 166 and print Error Message No. 1 if there is no Frequency Response List.

120. Go to DMAP No. 164 and print Error Message No. 2 if there is no Dynamics Load Table.

121. FRRD forms the dynamic load vectors $\{P_d\}$ and solves for the displacements using the following equation

$$[-M_{dd}\omega^2 + iB_{dd}\omega + K_{dd}]\{u_d\} = \{P_d\} .$$

122. Equivalence $\{P_p\}$ to $\{P_d\}$ if no constraints are applied.

123. VDR prepares solution set displacements, sorted by frequency, for output.

124. Go to DMAP No. 133 if there is no output request for the solution set.

125. Go to DMAP No. 131 if there is no output request for solution set displacements sorted by point number.

126. SDR3 sorts the solution set displacements by point number.

127. ØFP formats the requested solution set displacements, sorted by point number, prepared by SDR3 and places them on the system output file for printing.

128. XYTRAN prepares the input for requested X-Y plots of the solution set displacements vs. frequency.

129. XYPLØT prepares the requested X-Y plots of the solution set displacements vs. frequency.

130. Go to DMAP No. 133.

132. ØFP formats the requested solution set displacements, sorted by frequency, prepared by VDR and places them on the system output file for printing.

134. Go to DMAP No. 159 if there is no output request involving dependent degrees of freedom or forces and stresses.

135. Equivalence $\{u_d\}$ to $\{u_p\}$ if no constraints are applied.

136. Go to DMAP No. 138 if no constraints are applied.

137. SDR1 recovers dependent components of displacements

$$\{u_o\} = [G_o^d]\{u_d\} \quad , \qquad \left\{\begin{array}{c} u_d \\ \hline u_o \end{array}\right\} = \{u_f + u_e\} \quad ,$$

$$\left\{\begin{array}{c} u_f + u_e \\ \hline u_s \end{array}\right\} = \{u_n + u_e\} \quad , \qquad \{u_m\} = [G_m^d]\{u_f + u_e\} \quad ,$$

$$\left\{\begin{array}{c} u_n + u_e \\ \hline u_m \end{array}\right\} = \{u_p\}$$

and recovers single-point forces of constraint $\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\}$.

139. SDR2 calculates element forces (ØEFC1) and stresses (ØESC1) and prepares load vectors (ØPPC1), displacement vectors (ØUPVC1) and single-point forces of constraint (ØQPC1) for output and translation components of the displacement vector (PUGVC1), sorted by frequency.

140. Go to DMAP No. 151 if there are no output requests sorted by point number or element number.

141. SDR3 prepares requested output sorted by point number or element number.

142. ØFP formats the tables prepared by SDR3 sorted by point number or element number, and places them on the system output file for printing.

143. XYTRAN prepares the input for requested X-Y plots.

144. XYPLØT prepares the requested X-Y plots of displacements, forces, stresses, loads and single-point forces of constraint vs. frequency.

145. Go to DMAP No. 154 if there is no Power Spectral Density List.

146. RANDØM calculates power spectral density functions (PSDF) and autocorrelation functions (AUTØ) using the previously calculated frequency response.

147. Go to DMAP No. 154 if no RANDØM calculations are requested.

148. XYTRAN prepares the input for requested X-Y plots of the RANDØM output.

149. XYPLØT prepares the requested X-Y plots of autocorrelation functions and power spectral density functions.

150. Go to DMAP No. 154.

153. ØFP formats the frequency response output requests prepared by SDR2, sorted by frequency, and places them on the system output file for printing.

156. Go to DMAP No. 159 if no deformed structure plots are requested.

157. PLØT prepares all requested deformed structure and contour plots.

158. PRTMSG prints plotter data, engineering data and contour data for each deformed plot generated.

160. Go to DMAP No. 170 if no additional sets of direct input matrices need to be processed.

161. Go to DMAP No. 97 if additional sets of direct input matrices need to be processed.

162. Print Error Message No. 3 and terminate execution.

163. Go to DMAP No. 170 and make normal exit.

165. Print Error Message No. 2 and terminate execution.

167. Print Error Message No. 1 and terminate execution.

169. Print Error Message No. 4 and terminate execution.

3.9.3 <u>Output for Direct Frequency and Random Response</u>

The following printed output, sorted by frequency (SØRT1) or by point number or element number (SØRT2), is available, either as real and imaginary parts or magnitude and phase angle (0° - 360° lead), for the list of frequencies specified by ØFREQUENCY:

1. Displacements, velocities and accelerations for a list of PHYSICAL points (grid points and extra scalar points introduced for dynamic analysis) or SØLUTIØN points (points used in the formulation of the dynamic equation).
2. Nonzero components of the applied load vector and single-point forces of constraint for a list of PHYSICAL points.
3. Stresses and forces in selected elements (ALL available only for SØRT1).

The following plotter output is available for Frequency Response calculations:

1. Undeformed plot of the structural model.
2. Deformed shapes of the structural model for selected frequencies.
3. Contour plots of stresses and displacements for selected frequencies.
4. X-Y plot of any component of displacement, velocity or acceleration of a PHYSICAL point or SØLUTIØN point.
5. X-Y plot of any component of the applied load vector or single-point force of constraint.
6. X-Y plot of any stress or force component for an element.

The following plotter output is available for Random Response calculations:

1. X-Y plot of the power spectral density versus frequency for the response of selected components for points or elements.
2. X-Y plot of the autocorrelation versus time lag for the response of selected components for points or elements.

The data used for preparing the X-Y plots may be punched or printed in tabular form (see Section 4.3). This is the only form of printed output that is available for Random Response. Also, a printed summary is prepared for each X-Y plot which includes the maximum and minimum values of the plotted function.

3.9.4 <u>Case Control Deck for Direct Frequency and Random Response</u>

The following items relate to subcase definition and data selection for Direct Frequency and Random Response:

1. At least one subcase must be defined for each unique set of direct input matrices (K2PP, M2PP, B2PP) or frequencies.
2. Consecutive subcases for each set of direct input matrices or frequencies are used to define the loading conditions - one subcase for each dynamic loading condition.
3. Constraints must be defined above the subcase level.
4. DLØAD must be used to define a frequency-dependent loading condition for each subcase.
5. FREQUENCY must be used to select one, and only one, FREQ, FREQ1, or FREQ2 card from the Bulk Data Deck for each unique set of direct input matrices.
6. On restart following an unscheduled exit due to insufficient time, the subcase structure must be changed to reflect the sets of direct input matrices that were completed, and FREQUENCY must be changed to select a FREQ, FREQ1, or FREQ2 card that reflects any frequencies for which the response has already been determined. Otherwise, the previous calculations will be repeated.
7. ØFREQUENCY may be used above the subcase level or within each subcase to select a subset of the solution frequencies for output requests. The default is to use all solution frequencies.
8. If Random Response calculations are desired, RANDØM must be used to select RANDPS and RANDTi cards from the Bulk Data Deck. Only one ØFREQUENCY and FREQUENCY card can be used for each set of direct input matrices.

3.9.5 Parameters for Direct Frequency and Random Response

The following parameters are used in Direct Frequency and Random Response:

1. GRDPNT - optional. A positive integer value of this parameter will cause the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
2. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in EMA. Not recommended for use in hydroelastic problems.
3. G - optional. The real value of this parameter is used as a uniform structural damping coefficient in the direct formulation of dynamics problems. Not recommended for use in hydroelastic problems.
4. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT,

CPTRBSC - optional. These parameters will cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.

5. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.

6. AUTØSPC - reserved for future optional use. The default value is -1.

3.9.6 Automatic ALTERs for Automated Multi-stage Substructuring

The following lines of the Direct Frequency and Random Response, Rigid Format 8, are ALTERed in automated substructure analyses.

Phase 1: 4, 56, 88-120, 121-162

Phase 2: 4, 5-5, 10-20, 23-24, 43-53, 111-112, 118-118, 135-158

Phase 3: 87, 90-136, 138, 160-162

If APP DISP, SUBS is used, the user may also specify ALTERs. However, these must not interfere with the automatically generated DMAP statement ALTERs listed above. See Section 5.9 for a description and listing of the ALTERs which are automatically generated for substructuring.

3.9.7 Rigid Format Error Messages from Direct Frequency and Random Response

The following fatal errors are detected by the DMAP statements in the Direct Frequency and Random Reponse rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

DIRECT FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 1 - FREQUENCY RESPØNSE LIST REQUIRED FØR FREQUENCY RESPØNSE CALCULATIØNS.

Frequencies to be used in the solution of frequency response problems must be supplied on a FREQ, FREQ1, or FREQ2 card in the Bulk Data Deck and FREQ in the Case Control Deck must select a frequency response set.

DIRECT FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 2 - DYNAMIC LØADS TABLE REQUIRED FØR FREQUENCY RESPØNSE CALCULATIØNS.

Dynamic loads to be used in the solution of frequency response problems must be specified on an RLØAD1 or RLØAD2 card in the Bulk Data Deck and DLØAD in the Case Control Deck must select a dynamic load set.

DIRECT FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 3 - ATTEMPT TØ EXECUTE MØRE THAN 100 LØØPS.

An attempt has been made to use more than 100 sets of direct input matrices. This number may be increased by ALTERing the REPT instruction following the last ØFP instruction.

DIRECT FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 4 - MASS MATRIX REQUIRED FØR WEIGHT AND BALANCE CALCULATIØNS.

The mass matrix is null because either no elements were defined on Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

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3.10 DIRECT TRANSIENT RESPONSE

3.10.1 DMAP Sequence for Direct Transient Response

```
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OPTIONS IN EFFECT   GO     ERR=2   LIST    NODECK  NOREF   NOOSCAR

  1  BEGIN    DISP 09 - DIRECT TRANSIENT RESPONSE ANALYSIS - APR. 1984 $
  2  PRECHK   ALL $
  3  FILE     UDVT=APPEND/TOL=APPEND $
  4  PARAM    //*MPY*/CARDNO/0/0 $
  5  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  S,N,
              NOGPDT/ALWAYS=-1 $
  6  PLTTRAN  BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $
  7  PURGE    USET,GM,GO,KAA,BAA,MAA,K4AA,PST,KFS,QP,EST,ECT,PLTSETX,PLTPAR,
              GPSETS,ELSETS/NOGPDT $
  8  COND     LBL5,NOGPDT $
  9  GP2      GEOM2,EQEXIN/ECT $
 10  PARAML   PCDB//*PRES*////JUMPPLOT $
 11  PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $
 12  COND     P1,JUMPPLOT $
 13  PLTSET   PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/S,N,
              JUMPPLOT=-1 $
 14  PRTMSG   PLTSETX// $
 15  PARAM    //*MPY*/PLTFLG/1/1 $
 16  PARAM    //*MPY*/PFILE/0/0 $
 17  COND     P1,JUMPPLOT $
 18  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
              NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $
 19  PRTMSG   PLOTX1// $
 20  LABEL    P1 $
 21  GP3      GEOM3,EQEXIN,GEOM2/SLT,GPTT/NOGRAV $
 22  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/LUSET/S,N,NOSIMP=
              -1/1/S,N,NOGENL=-1/S,N,GENEL $
 23  PURGE    K4GG,GPST,OGPST,MGG,BGG,K4NN,K4FF,K4AA,MNN,MFF,MAA,BNN,BFF,BAA,
              KGGX/NOSIMP/OGPST/GENEL $
 24  COND     LBL1,NOSIMP $
 25  PARAM    //*ADD*/NOKGGX/1/0 $
 26  PARAM    //*ADD*/NOMGG/1/0 $
 27  PARAM    //*ADD*/NOBGG=-1/1/0 $ .
 28  PARAM    //*ADD*/NOK4GG/1/0 $
 29  EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,BELM,BDICT/   S,
              N,NOKGGX/S,N,NOMGG/S,N,NOBGG/S,N,NOK4GG//C,Y,COUPMASS/C,Y,
```

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```
               CPBAR/C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,
               CPTRIA2/C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC $
30   PURGE     KGGX,GPST/NOKGGX/MGG/NOMGG $
31   COND      LBLKGGX,NOKGGX $
32   EMA       GPECT,KDICT,KELM/KGGX,GPST $
33   LABEL     LBLKGGX $
34   COND      LBLMGG,NOMGG $
35   EMA       GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $
36   LABEL     LBLMGG $
37   COND      LBLBGG,NOBGG $
38   EMA       GPECT,BDICT,BELM/BGG, $
39   LABEL     LBLBGG $
40   COND      LBLK4GG,NOK4GG $
41   EMA       GPECT,KDICT,KELM/K4GG,/NOK4GG $
42   LABEL     LBLK4GG $
43   PURGE     MNN,MFF,MAA/NOMGG $
44   PURGE     BNN,BFF,BAA/NOBGG $
45   COND      LBL1,GRDPNT $
46   COND      ERROR3,NOMGG $
47   GPWG      BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $
48   OFP       OGPWG,,,,,//S,N,CARDNO $
49   LABEL     LBL1 $
50   EQUIV     KGGX,KGG/NOGENL $
51   COND      LBL11,NOGENL $
52   SMA3      GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $
53   LABEL     LBL11 $
54   PARAM     //*MPY*/NSKIP/0/0 $
55   GP4       CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,USET,ASET/ LUSET/
               S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/S,N,NSKIP/S,
               N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/ S,Y,AUTOSPC $
56   PURGE     GM,GMD/MPCF1/GO,GOD/OMIT/KFS,PST,QP/SINGLE $
57   COND      LBL4,GENEL $
58   COND      LBL4,NOSIMP $
59   PARAM     //*EQ*/GPSPFLG/AUTOSPC/0 $
60   COND      LBL4,GPSPFLG $
61   GPSP      GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
62   OFP       OGPST,,,,,//S,N,CARDNO $
63   LABEL     LBL4 $
64   EQUIV     KGG,KNN/MPCF1/MGG,MNN/MPCF1/ BGG,BNN/MPCF1/K4GG,K4NN/MPCF1 $
```

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```
65  COND      LBL2,MPCF1 $
66  MCE1      USET,RG/GM $
67  MCE2      USET,GM,KGG,MGG,BGG,K4GG/KNN,MNN,BNN,K4NN $
68  LABEL     LBL2 $
69  EQUIV     KNN,KFF/SINGLE/MNN,MFF/SINGLE/BNN,BFF/SINGLE/K4NN,K4FF/SINGLE $
70  COND      LBL3,SINGLE $
71  SCE1      USET,KNN,MNN,BNN,K4NN/KFF,KFS, ,MFF,BFF,K4FF $
72  LABEL     LBL3 $
73  EQUIV     KFF,KAA/OMIT $
74  EQUIV     MFF,MAA/OMIT $
75  EQUIV     BFF,BAA/OMIT $
76  EQUIV     K4FF,K4AA/OMIT $
77  COND      LBL5,OMIT $
78  SMP1      USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
79  COND      LBLM,NOMGG $
80  SMP2      USET,GO,MFF/MAA $
81  LABEL     LBLM $
82  COND      LBLB,NOBGG $
83  SMP2      USET,GO,BFF/BAA $
84  LABEL     LBLB $
85  COND      LBL5,NOK4GG $
86  SMP2      USET,GO,K4FF/K4AA $
87  LABEL     LBL5 $
88  DPD       DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPOOL,DLT,,,NLFT,TRL,,
              EQDYN/LUSET/S,N,LUSETD/NOTFL/S,N,NODLT/NOPSDL/  NOFRL/S,N,
              NONLFT/S,N,NOTRL/NOEED//S,N,NOUE $
89  COND      ERROR1,NOTRL $
90  PURGE     PNLD/NONLFT$
91  EQUIV     GO,GOD/NOUE/GM,GMD/NOUE $
92  BMG       MATPOOL,BGPDT,EQEXIN,CSTM/BDPOOL/S,N,NOKBFL/S,N,NOABFL/ S,N,
              MFACT $
93  PARAM     //*AND*/NOFL/NOABFL/NOKBFL $
94  PURGE     KBFL/NOKBFL/ ABFL/NOABFL $
95  COND      LBLFL3,NOFL $
96  MTRXIN,   ,BDPOOL,EQDYN,,/ABFL,KBFL,/LUSETD/S,N,NOABFL/S,N,NOKBFL/0 $
97  LABEL     LBLFL3 $
98  MTRXIN    CASECC,MATPOOL,EQDYN,,TFPOOL/K2DPP,M2DPP,B2PP/LUSETD/S,N,
              NOK2DPP/S,N,NOM2DPP/S,N,NOB2PP $
```


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```
 99  PARAM   //*AND*/NOM2PP/NOABFL/NOM2DPP $
100  PARAM   //*AND*/NOK2PP/NOFL /NOK2DPP $
101  EQUIV   K2DPP,K2PP/NOFL/M2DPP,M2PP/NOABFL $
102  COND    LBLFL2,NOFL $
103  ADD5    ABFL,KBFL,K2DPP,,/K2PP/(-1.0,0.0) $
104  COND    LBLFL2,NOABFL $
105  TRNSP   ABFL/ABFLT $
106  ADD     ABFLT,M2DPP/M2PP/MFACT $
107  LABEL   LBLFL2 $
108  PARAM   //*AND*/KDEKA/NOUE/NOK2PP $
109  PARAM   //*AND*/MDEMA/NOUE/NOM2PP $
110  PARAM   //*AND*/KDEK2/NOGENL/NOSIMP $
111  PURGE   K2DD/NOK2PP/M2DD/NOM2PP/B2DD/NOB2PP $
112  EQUIV   M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA/MAA,MDD/MDEMA/  KAA,
             KDD/KDEKA $
113  COND    LBL16,NOGPDT $
114  GKAD    USETD,GM,GO,KAA,BAA,MAA,K4AA,K2PP,M2PP,B2PP/KDD,BDD,MDD,GMD,
             GOD,K2DD,M2DD,B2DD/*TRANRESP*/*DISP*/*DIRECT*/C,Y,G=0.0/C,Y,W3=
             0.0/C,Y,W4=0.0/NOK2PP/NOM2PP/NOB2PP/ MPCF1/SINGLE/OMIT/NOUE/
             NOK4GG/NOBGG/KDEK2/-1 $
115  LABEL   LBL16 $
116  EQUIV   M2DD,MDD/NOSIMP/B2DD,BDD/NOGPDT/K2DD,KDD/KDEK2 $
117  PARAM   //*ADD*/NEVER/1/0 $
118  PARAM   //*MPY*/REPEATT/1/-1 $
---------------------------------------------  Top of Dynamic Load Set Loop
119  LABEL   LBL13 $
120  PURGE   PNLD,OUDV1,OPNL1,OUDV2,OPNL2,XYPLTTA,OPP1,OQP1,OUPV1,OES1,OEF1,
             OPP2,OQP2,OUPV2,OES2,OEF2,PLOTX2,XYPLTT/NEVER $
121  CASE    CASECC,/CASEXX/*TRAN*/S,N,REPEATT/S,N,NOLOOP $
122  PARAM   //*MPY*/NCOL/0/1 $
123  TRLG    CASEXX,USETD,DLT,SLT,BGPDT,SIL,CSTM,TRL,DIT,GMD,GOD,,EST,MGG/
             PPT,PST,PDT,PD,,TOL/S,N,NOSET/NCOL $
124  EQUIV   PPT,PDT/NOSET $
125  TRD     CASEXX,TRL,NLFT,DIT,KDD,BDD,MDD,PD/UDVT,PNLD/*DIRECT*/  NOUE/
             NONCUP/S,N,NCOL/C,Y,ISTART $
126  VDR     CASEXX,EQDYN,USETD,UDVT,TOL,XYCDB,PNLD/OUDV1,OPNL1/ *TRANRESP*/
             *DIRECT*/0/S,N,NOD/S,N,NOP/0 $
127  COND    LBL15,NOD $
128  SDR3    OUDV1,OPNL1,,,,/OUDV2,OPNL2,,,, $
129  OFP     OUDV2,OPNL2,,,,//S,N,CARDNO $
130  XYTRAN  XYCDB,OUDV2,OPNL2,,,/XYPLTTA/*TRAN*/*DSET*/S,N,PFILE/S,N,
             CARDNO $
131  XYPLOT  XYPLTTA// $
```

```
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132  LABEL    LBL15 $
133  PARAM    //*AND*/PJUMP/NOP/JUMPPLOT $
134  COND     LBL16,PJUMP $
135  EQUIV    UDVT,UPV/NOA $
136  COND     LBL17,NOA $
137  SDR1     USETD,,UDVT,,,GOD,GMD,PST,KFS,,/UPV,,QP/1/*DYNAMICS* $
138  LABEL    LBL17 $
139  SDR2     CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,BGPDP,TOL,QP,UPV,EST,XYCDB,
              PPT/OPP1,OQP1,OUPV1,OES1,OEF1,PUGV/*TRANRESP* $
140  SDR3     OPP1,OQP1,OUPV1,OES1,OEF1,/OPP2,OQP2,OUPV2,OES2,OEF2, $
141  OFP      OPP2,OQP2,OUPV2,OEF2,OES2,//S,N,CARDNO $
142  COND     P2,JUMPPLOT $
143  PLOT     PLTPAR,GPSETS,ELSETS,CASEXX,BGPDT,EQEXIN,SIP,,PUGV,GPECT,OES1/
              PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $
144  PRTMSG   PLOTX2// $
145  LABEL    P2 $
146  XYTRAN   XYCDB,OPP2,OQP2,OUPV2,OES2,OEF2/XYPLTT/*TRAN*/*PSET*/S,N,PFILE/
              S,N,CARDNO $
147  XYPLOT   XYPLTT// $
148  LABEL    LBL18 $
149  COND     FINIS,REPEATT $
150  REPT     LBL13,100 $
151  PRTPARM  //-2/*DIRTRD* $          Bottom of Dynamic Load Set Loop
152  JUMP     FINIS $
153  LABEL    ERROR1 $
154  PRTPARM  //-1/*DIRTRD* $
155  LABEL    ERROR3 $
156  PRTPARM  //-3/*DIRTRD* $
157  LABEL    FINIS $
158  PURGE    DUMMY/ALWAYS $
159  END      $
```

3.10.2 Description of DMAP Operations for Direct Transient Response

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

8. Go to DMAP No. 87 if there is only Direct Matrix Input.

9. GP2 generates Element Connection Table with internal indices.

12. Go to DMAP No. 20 if there are no structure plot requests.

13. PLTSET transforms user input into a form used to drive the structure plotter.

14. PRTMSG prints error messages associated with the structure plotter.

17. Go to DMAP No. 20 if no undeformed structure plots are requested.

18. PLØT generates all requested undeformed structure plots.

19. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

21. GP3 generates Grid Point Temperature Table.

22. TA1 generates element tables for use in matrix assembly and stress recovery.

24. Go to DMAP No. 49 if there are no structural elements.

29. EMG generates structural element stiffness, mass, and damping matrix tables and dictionaries for later assembly by the EMA module.

31. Go to DMAP No. 33 if no stiffness matrix is to be assembled.

32. EMA assembles stiffness matrix $[K^x_{gg}]$ and Grid Point Singularity Table.

34. Go to DMAP No. 36 if no mass matrix is to be assembled.

35. EMA assembles mass matrix $[M_{gg}]$.

37. Go to DMAP No. 39 if no viscous damping matrix is to be assembled.

38. EMA assembles viscous damping matrix $[B_{gg}]$.

40. Go to DMAP No. 42 if no structural damping matrix is to be assembled.

41. EMA assembles structural damping matrix $[K^4_{gg}]$.

45. Go to DMAP No. 49 if no weight and balance information is requested.

46. Go to DMAP No. 155 and print Error Message No. 3 if no mass matrix exists.

47. GPWG generates weight and balance information.

48. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

50. Equivalence $[K^x_{gg}]$ to $[K_{gg}]$ if there are no general elements.

51. Go to DMAP No. 53 if there are no general elements.

52. SMA3 adds general elements to $[K^x_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

55. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations $[R_g]\{u_g\} = 0$.

57. Go to DMAP No. 63 if general elements are present.

58. Go to DMAP No. 63 if there are no structural elements.

60. Go to DMAP No. 63 if no potential grid point singularities exist.

61. GPSP generates a table of potential grid point singularities.

62. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

64. Equivalence $[K_{gg}]$ to $[K_{nn}]$, $[M_{gg}]$ to $[M_{nn}]$, $[B_{gg}]$ to $[B_{nn}]$ and $[K^4_{gg}]$ to $[K^4_{nn}]$ if no multipoint constraints exist.

65. Go to DMAP No. 68 if no multipoint constraints exist.

66. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

67. MCE2 partitions stiffness, mass and damping matrices

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right] , \qquad [M_{gg}] = \left[\begin{array}{c|c} \bar{M}_{nn} & M_{nm} \\ \hline M_{mn} & M_{mm} \end{array}\right]$$

$$[B_{gg}] = \left[\begin{array}{c|c} \bar{B}_{nn} & B_{nm} \\ \hline B_{mn} & B_{mm} \end{array}\right] \quad \text{and} \quad [K^4_{gg}] = \left[\begin{array}{c|c} \bar{K}^4_{nn} & K^4_{nm} \\ \hline K^4_{mn} & K^4_{mm} \end{array}\right]$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] ,$$

$$[M_{nn}] = [\bar{M}_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m] ,$$

$$[B_{nn}] = [\bar{B}_{nn}] + [G_m^T][B_{mn}] + [B_{mn}^T][G_m] + [G_m^T][B_{mm}][G_m] ,$$

$$[K^4_{nn}] = [\bar{K}^4_{nn}] + [G_m^T][K^4_{mn}] + [K^4_{mn}]^T[G_m] + [G_m^T][K^4_{mm}][G_m] .$$

69. Equivalence $[K_{nn}]$ to $[K_{ff}]$, $[M_{nn}]$ to $[M_{ff}]$, $[B_{nn}]$ to $[B_{ff}]$ and $[K^4_{nn}]$ to $[K^4_{ff}]$ if no single-point constraints exist.

70. Go to DMAP No. 72 if no single-point constraints exist.

71. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right] , \qquad [M_{nn}] = \left[\begin{array}{c|c} M_{ff} & M_{fs} \\ \hline M_{sf} & M_{ss} \end{array}\right] ,$$

$$[B_{nn}] = \left[\begin{array}{c|c} B_{ff} & B_{fs} \\ \hline B_{sf} & B_{ss} \end{array}\right] \text{ and } \qquad [K^4_{nn}] = \left[\begin{array}{c|c} K^4_{ff} & K^4_{fs} \\ \hline K^4_{sf} & K^4_{ss} \end{array}\right] .$$

73. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

74. Equivalence $[M_{ff}]$ to $[M_{aa}]$ if no omitted coordinates exist.

75. Equivalence $[B_{ff}]$ to $[B_{aa}]$ if no omitted coordinates exist.

76. Equivalence $[K^4_{ff}]$ to $[K^4_{aa}]$ if no omitted coordinates exist.

77. Go to DMAP No. 87 if no omitted coordinates exist.

78. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right] ,$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K^1_{aa}] = [K_{aa}] + [K_{ao}][G_o]$.

79. Go to DMAP No. 81 if there is no mass matrix.

80. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \left[\begin{array}{c|c} M_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right] ,$$

and performs matrix reduction

$$[M^1_{aa}] = [M_{aa}] + [M_{ao}][G_o] + [M_{ao}G_o]^T + [G^T_o][M_{oo}][G_o] .$$

82. Go to DMAP No. 84 if there is no viscous damping matrix.

83. SMP2 partitions constrained viscous damping matrix

$$[B_{ff}] = \left[\begin{array}{c|c} B_{aa} & B_{ao} \\ \hline B_{oa} & B_{oo} \end{array}\right] ,$$

and performs matrix reduction

$$[B^1_{aa}] = [B_{aa}] + [B_{ao}][G_o] + [B_{ao}G_o]^T + [G_o^T][B_{oo}][G_o]$$

85. Go to DMAP No. 87 if there is no structural damping matrix.

86. SMP2 partitions constrained structural damping matrix

$$[K^4_{ff}] = \left[\begin{array}{c|c} K^4_{aa} & K^4_{ao} \\ \hline K^4_{oa} & K^4_{oo} \end{array}\right],$$

and performs matrix reduction

$$[K^4_{aa}] = [K^4_{aa}] + [K^4_{ao}][G_o] + [K^4_{ao}G_o]^T + [G_o^T][K^4_{oo}][G_o]$$

88. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating the internal and external grid point numbers (GPLD), including extra points introduced for dynamic analysis (SILD), and prepares Transfer Function Pool (TFPØØL), Dynamics Load Table (DLT), Nonlinear Function Table (NLFT), and Transient Response List (TRL).

89. Go to DMAP No. 63 if no potential grid point singularities exist.

91. Equivalence $[G_o]$ to $[G^d_o]$ and $[G_m]$ to $[G^d_m]$ if there are no extra points introduced for dynamic analysis.

92. BMG generates DMIG card images describing the interconnection of the fluid and the structure.

95. Go to DMAP No. 97 if no fluid-structure interface is defined.

96. MTRXIN generates fluid boundary matrices $[A_{b,f\ell}]$ and $[K_{b,f\ell}]$ if a fluid-structure interface is defined. The matrix $[K_{b,f\ell}]$ is generated only for a nonzero gravity in the field.

98. MTRXIN selects the direct input matrices $[K^{2d}_{pp}]$, $[M^{2d}_{pp}]$ and $[B^2_{pp}]$.

101. Equivalence $[K^2_{pp}]$ to $[K^{2d}_{pp}]$ if no fluid-structure interface is defined and equivalence $[M^2_{pp}]$ to $[M^{2d}_{pp}]$ if there is no $[A_{b,f\ell}]$.

102. Go to DMAP No. 107 if no fluid-structure interface is defined.

103. ADD5 adds $[K_{b,f\ell}]$ and $[K^{2d}_{pp}]$ and subtracts $[A_{b,f\ell}]$ from them to form $[K^2_{pp}]$.

104. Go to DMAP No. 107 if there is no $[A_{b,f\ell}]$.

105. Transpose $[A_{b,f\ell}]$ to obtain $[A_{b,f\ell}]^T$.

106. ADD assembles input matrix $[M^2_{pp}]$ = MFACT $[A_{b,f\ell}]^T + [M^{2d}_{pp}]$.

112. Equivalence $[M^2_{pp}]$ to $[M^2_{dd}]$, $[B^2_{pp}]$ to $[B^2_{dd}]$ and $[K^2_{pp}]$ to $[K^2_{dd}]$ if no constraints

are applied, $[M_{aa}]$ to $[M_{dd}]$ if there are no direct input mass matrices and no extra points, and $[K_{aa}]$ to $[K_{dd}]$ if there are no direct input stiffness matrices and no extra points.

113. Go to DMAP No. 115 if only extra points are defined.

114. GKAD assembles stiffness, mass, and damping matrices for use in Direct Transient Response:

$$[K_{dd}] = [K^1_{dd}] + [K^2_{dd}] \ ,$$

$$[M_{dd}] = [M^1_{dd}] + [M^2_{dd}] \ ,$$

and

$$[B_{dd}] = [B^1_{dd}] + [B^2_{dd}] + \frac{g}{\omega_3}[K^1_{dd}] + \frac{1}{\omega_4}[K^4_{dd}] \ ,$$

where

$$\left[\begin{array}{c|c} K_{aa} & 0 \\ \hline 0 & 0 \end{array}\right] \quad [K^1_{dd}],$$

$$\left[\begin{array}{c|c} M_{aa} & 0 \\ \hline 0 & 0 \end{array}\right] \quad [M^1_{dd}],$$

$$\left[\begin{array}{c|c} B_{aa} & 0 \\ \hline 0 & 0 \end{array}\right] \quad [B^1_{dd}],$$

and

$$\left[\begin{array}{c|c} K^4_{aa} & 0 \\ \hline 0 & 0 \end{array}\right] \quad [K^4_{dd}].$$

All matrices are real.

116. Equivalence $[B^2_{dd}]$ to $[B_{dd}]$ if all damping is Direct Matrix Input, $[M^2_{dd}]$ to $[M_{dd}]$ if all mass is Direct Matrix Input and $[K^2_{dd}]$ to $[K_{dd}]$ is all stiffness is Direct Matrix Input.

119. Beginning of loop for additional dynamic load sets.

121. CASE extracts the appropriate record from CASECC corresponding to the current loop and copies it into CASEXX.

123. TRLG generates matrices of loads versus time. $\{P^t_p\}$, $\{P^t_s\}$, and $\{P^t_d\}$ are generated with one column per output time step. $\{P_d\}$ is generated with one column per solution time step, and the Transient Output List (TØL) is a list of output time steps.

124. Equivalence $\{P^t_p\}$ to $\{P^t_d\}$ if the d and p sets are the same.

125. TRD forms the linear, $\{P_d\}$, and nonlinear, $\{P_d^{n\ell}\}$, dynamic load vectors and integrates the equations of motion (using the standard or alternate starting procedure) over specified time periods to solve for the displacements, velocities, and accelerations, using the following equation

$$[M_{dd}p^2 + B_{dd}p + K_{dd}]\{u_d\} = \{P_d\} + \{P_d^{n\ell}\} .$$

126. VDR prepares displacements, velocities and accelerations, sorted by time step, for output using only the solution set degrees of freedom.

127. Go to DMAP No. 132 if there is no output request for the solution set.

128. SDR3 prepares the requested output of the solution set displacements, velocities, accelerations and nonlinear load vectors sorted by point number of element number.

129. ØFP formats the tables prepared by SDR3 sorted by point number or element number and places them on the system output file for printing.

130. XYTRAN prepares the input for requested X-Y plots of the solution set quantities.

131. XYPLØT prepares the requested X-Y plots of the solution set displacements, velocities, accelerations and nonlinear load vectors vs. time.

134. Go to DMAP No. 148 if no further output is requested.

135. Equivalence $\{u_d\}$ to $\{u_p\}$ if no constraints are applied.

136. Go to DMAP No. 138 if no constraints are applied.

137. SDR1 recovers dependent components of displacements

$$\{u_o\} = [G_o^d]\{u_d\} , \qquad \left\{\begin{array}{c} u_d \\ \hline u_o \end{array}\right\} = \{u_f + u_e\} ,$$

$$\left\{\begin{array}{c} u_f + u_e \\ \hline u_s \end{array}\right\} = \{u_n + u_e\} , \qquad \{u_m\} = [G_m^d]\{u_f + u_e\} ,$$

$$\left\{\begin{array}{c} u_n + u_e \\ \hline u_m \end{array}\right\} = \{u_p\}$$

and recovers single-point forces of constraint $\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\}$.

139. SDR2 calculates element forces (ØEF1) and stresses (ØES1) and prepares load vectors (ØPP1), displacement, velocity and acceleration vectors (ØUPV1) and single-point forces of constraint (ØQP1) for output and translation components of the displacement vector (PUGV) sorted by time step.

140. SDR3 prepares requested output sorted by point number of element number.

141. ØFP formats the tables prepared by SDR3 for output sorted by point number of element number and places them on the system output file for printing.

142. Go to DMAP No. 145 if no deformed structure plots are requested.

143. PLØT prepares all requested deformed structure and contour plots.

144. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.

146. XYTRAN prepares the input for requested X-Y plots.

147. XYPLØT prepares the requested X-Y plots of displacements, velocities, accelerations, forces, stresses, loads and single-point forces of constraint versus time.

149. Go to DMAP No. 157 if no additional dynamic load sets need to be processed.

150. Go to DMAP No. 119 if additional dynamic load sets need to be processed.

151. Print Error Message No. 2 and terminate execution.

152. Go to DMAP No. 157 and make normal exit.

154. Print Error Message No. 1 and terminate execution.

156. Print Error Message No. 3 and terminate execution.

3.10.3 Output for Direct Transient Response

The following printed output, sorted by point number or element number (SØRT2), is available at selected multiples of the integration time step:

1. Displacements, velocities, and accelerations for a list of PHYSICAL points (grid points and extra scalar points introduced for dynamic analysis) or SØLUTIØN points (points used in the formulation of the dynamic equation).
2. Nonzero components of the applied load vector and single-point forces of constraint for a list of PHYSICAL points.
3. Nonlinear force vector for a list of SØLUTIØN points.
4. Stresses and forces in selected elements (All not allowed).

The following plotter output is available:

1. Undeformed plot of the structural model.
2. Deformed shapes of the structural model for selected time intervals.
3. Contour plots of stresses and displacements for selected time intervals.
4. X-Y plot of any component of displacement, velocity, or acceleration of a PHYSICAL point or a SØLUTIØN point.
5. X-Y plot of any component of the applied load vector, nonlinear force vector, or single-point force of constraint.
6. X-Y plot of any stress or force component for an element.

The data used for preapring the X-Y plots may be punched or printed in tabular form (see Section 4.3). Also, a printed summary is prepared for each X-Y plot which includes the maximum and minimum values of the plotted function.

3.10.4 Case Control Deck for Direct Transient Response

The following items relate to subcase definition and data selection for Direct Transient Response:

1. One subcase must be defined for each dynamic loading condition.
2. DLØAD and/or NØNLINEAR must be used to define a time-dependent loading condition for each subcase.
3. All constraints must be defined above the subcase level.
4. TSTEP must be used to select the time-step intervals to be used for integration and output in each subcase.

5. If nonzero initial conditions are desired, IC must be used to select a TIC card in the Bulk Data Deck.

6. On restart following an unscheduled exit due to insufficient time, the subcase structure should be changed to reflect any completed loading conditions. The TSTEP selections must be changed if it is desired to resume the integration at the point terminated.

3.10.5 Parameters for Direct Transient Response

The following parameters are used in Direct Transient Response:

1. GRDPNT - optional. A positive integer value of this parameter will cause the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.

2. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in EMA. Not recommended for use in hydroelastic problems.

3. G - optional. The real value of this parameter is used as a uniform structural damping coefficient in the direct formulation of dynamics problems. Not recommended for use in hydroelastic problems.

4. W3 and W4 - optional. The values of these parameters are used as pivotal frequencies for uniform structural damping and element structural damping respectively. W3 is required if uniform structural damping is desired. W4 is required if structural damping is desired for any of the structural elements. See page 9.3-8 of the Theoretical Manual.

5. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters will cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.

6. ISTART - optional. A positive value of this parameter will cause the TRD module to use the second (or alternate) starting method (see Section 11.4 of the Theoretical Manual). The alternate starting method is recommended when initial accelerations are significant and when the mass matrix is non-singular.

7. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.

8. AUTØSPC - reserved for future optional use. The default value is -1.

3.10.6 The CONTINUE Feature

In transient analysis, it is frequently necessary to continue the integration of the coupled equations beyond the last (or from any earlier intermediate) output time for which the solution was obtained in a previous run. The CONTINUE feature (see Section 11.4.2 of the Theoretical Manual for details) makes it possible to do this without re-executing the entire problem.

In order to use the CONTINUE feature, the user should employ the following steps:

1. Request a checkpoint of a coupled transient analysis problem.
2. Check to ensure that the solution for at least one output time is computed in this run and that the TØL (list of output times) and UDVT (displacement - velocity - acceleration) files are successfully checkpointed.
3. Restart the problem by changing any one or more of several cards either in the Case Control Deck (DLØAD, NØNLINEAR, TSTEP cards) and/or in the Bulk Data Deck (TSTEP, DAREA, DLØAD, FØRCE, etc.) that define either the dynamic loading and/or the time step selection. Ensure that the following conditions are satisfied.
   a. The structural model and the constraint data for the restart must be the same as that used in the checkpoint run.
   b. The dynamic loading and/or the time step selection in the restart need not be the same as that used in the checkpoint run.
   c. If the user wishes to continue the integration from an intermediate (rather than from the last) output time of the checkpoint run, a DMAP alter should be employed in the Executive Control Deck to reset the parameter NCØL to the appropriate value by means of a PARAM statement just before the TRLG module in the DMAP sequence. (See Section 11.4.2 of the Theoretical Manual for details).
4. Note that the output of the restart does not include the solutions of the checkpoint run, but only those solutions that are computed by the restart. Also, any initial conditions specified in the data for the restart are ignored since the solution is continued by using the displacements, velocities and accelerations corresponding to the specified output time of the checkpoint run as initial conditions.

3.10.7 Automatic ALTERs for Automated Multi-stage Substructuring

The following lines of the Direct Transient Response, Rigid Format 9, are ALTERed in automated substructue analyses.

Phase 1: 4, 56, 88-124, 125-151

Phase 2: 4, 5-5, 10-20, 23-24, 43-53, 109-110, 116-116, 135-147

Phase 3: 87, 92-136, 138, 149-151

If APP DISP, SUBS is used, the user may also specify ALTERs. However, these must not interfere with the automatically generated DMAP statement ALTERs listed above. See Section 5.9 for a description and listing of the ALTERs which are automatically generated for substructuring.

3.10.8 Rigid Format Error Messages from Direct Transient Response

The following fatal errors are detected by the DMAP statements in the Direct Transient Response rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

DIRECT TRANSIENT RESPØNSE ERRØR MESSAGE NØ. 1 - TRANSIENT RESPØNSE LIST REQUIRED FØR TRANSIENT RESPØNSE CALCULATIONS.

Time step intervals to be used must be specified on a TSTEP card in the Bulk Data Deck and a TSTEP selection must be made in the Case Control Deck.

DIRECT TRANSIENT RESPØNSE ERRØR MESSAGE NØ. 2 - ATTEMPT TØ EXECUTE MØRE THAN 100 LØØPS.

An attempt has been made to use more than 100 dynamic load sets. This number may be increased by ALTERing the REPT instruction following the last XYPLØT instruction.

DIRECT TRANSIENT RESPØNSE ERRØR MESSAGE NØ. 3 - MASS MATRIX REQUIRED FØR WEIGHT AND BALANCE CALCULATIØNS.

The mass matrix is null because either no elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

3.11 MODAL COMPLEX EIGENVALUE ANALYSIS

3.11.1 DMAP Sequence for Modal Complex Eigenvalue Analysis

```
RIGID FORMAT DMAP LISTING
RELEASE APR. 1984

DISPLACEMENT APPROACH, RIGID FORMAT 10

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


OPTIONS IN EFFECT   GO     ERR=2   LIST    NODECK  NOREF   NOOSCAR

   1  BEGIN    DISP 10 - MODAL COMPLEX EIGENVALUE ANALYSIS - APR. 1984 $
   2  PRECHK   ALL $
   3  FILE     GOD=SAVE/GMD=SAVE/LAMA=APPEND/PHIA=APPEND $
   4  PARAM    //*MPY*/CARDNO/0/0 $
   5  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  NOGPDT/
               MINUS1=-1 $
   6  PLTTRAN  BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $
   7  GP2      GEOM2,EQEXIN/ECT $
   8  PARAML   PCDB//*PRES*////JUMPPLOT $
   9  PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $
  10  COND     P1,JUMPPLOT $
  11  PLTSET   PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/   S,N,
               JUMPPLOT $
  12  PRTMSG   PLTSETX// $
  13  PARAM    //*MPY*/PLTFLG/1/1 $
  14  PARAM    //*MPY*/PFILE/0/0 $
  15  COND     P1,JUMPPLOT $
  16  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
               NSIL/LUSET/JUMPPLOT/PLTFLG/S,N,PFILE $
  17  PRTMSG   PLOTX1// $
  18  LABEL    P1 $
  19  GP3      GEOM3,EQEXIN,GEOM2/,GPTT/NOGRAV $
  20  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/LUSET/S,N,NOSIMP/1/
               S,N,NOGENL/S,N,GENEL $
  21  COND     ERROR5,NOSIMP $
  22  PURGE    OGPST/GENEL $
  23  PARAM    //*ADD*/NOKGGX/1/0 $
  24  PARAM    //*ADD*/NOMGG/1/0 $
  25  EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,/S,N,NOKGGX/ S,
               N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/C,Y,CPQUAD1/C,Y,
               CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/  C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,
               CPTRPLT/C,Y,CPTRBSC $
  26  PURGE    KGGX,GPST/NOKGGX $
  27  COND     JMPKGGX,NOKGGX $
  28  EMA      GPECT,KDICT,KELM/KGGX,GPST $
  29  LABEL    JMPKGGX $
```


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RIGID FORMAT DMAP LISTING
RELEASE APR. 1984

DISPLACEMENT APPROACH, RIGID FORMAT 10

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
30  COND     ERROR1,NOMGG $
31  EMA      GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $
32  COND     LGPWG,GRDPNT $
33  GPWG     BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $
34  OFP      OGPWG,,,,,//S,N,CARDNO $
35  LABEL    LGPWG $
36  EQUIV    KGGX,KGG/NOGENL $
37  COND     LBL11,NOGENL $
38  SMA3     GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $
39  LABEL    LBL11 $
40  PARAM    //*MPY*/NSKIP/0/0 $
41  GP4      CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,USET,ASET/ LUSET/
             S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/S,N,NSKIP/S,
             N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/ S,Y,AUTOSPC $
42  PARAM    //*AND*/NOSR/REACT/SINGLE $
43  PURGE    GM,GMD/MPCF1/GO,GOD/OMIT/KFS/SINGLE/QPC/NOSR/KLR,KRR,MLR,MRR,
             DM,MR/REACT $
44  COND     LBL4,GENEL $
45  PARAM    //*EQ*/GPSPFLG/AUTOSPC/0 $
46  COND     LBL4,GPSPFLG $
47  GPSP     GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
48  OFP      OGPST,,,,,//S,N,CARDNO $
49  LABEL    LBL4 $
50  EQUIV    KGG,KNN/MPCF1/MGG,MNN/MPCF1 $
51  COND     LBL2,MPCF1 $
52  MCE1     USET,RG/GM $
53  MCE2     USET,GM,KGG,MGG,,/KNN,MNN,, $
54  LABEL    LBL2 $
55  EQUIV    KNN,KFF/SINGLE/MNN,MFF/SINGLE $
56  COND     LBL3,SINGLE $
57  SCE1     USET,KNN,MNN,,/KFF,KFS,,MFF,, $
58  LABEL    LBL3 $
59  EQUIV    KFF,KAA/OMIT $
60  EQUIV    MFF,MAA/OMIT $
61  COND     LBL5,OMIT $
62  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
63  SMP2     USET,GO,MFF/MAA $
64  LABEL    LBL5 $
65  COND     LBL6,REACT $
```

ORIGINAL PAGE IS
OF POOR QUALITY

RIGID FORMAT DMAP LISTING
RELEASE APR. 1984

DISPLACEMENT APPROACH, RIGID FORMAT 10

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
66  RBMG1    USET,KAA,MAA/KLL,KLR,KRR,MLL,MLR,MRR $
67  RBMG2    KLL/LLL $
68  RBMG3    LLL,KLR,KRR/DM $
69  RBMG4    DM,MLL,MLR,MRR/MR $
70  LABEL    LBL6 $
71  DPD      DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPOOL,,,,,EED,EQDYN/
             LUSET/S,N,LUSETD/NOTFL/NODLT/NOPSDL/NOFRL/NONLFT/NOTRL/S,N,
             NOEED//S,N,NOUE $
72  COND     ERROR2,NOEED $
73  EQUIV    GO,GOD/NOUE/GM,GMD/NOUE $
74  PARAM    //*MPY*/NEIGV/1/-1 $
75  READ     KAA,MAA,MR,DM,EED,USET,CASECC/LAMA,PHIA,MI,OEIGS/*MODES*/S,N,
             NEIGV $
76  OFP      OEIGS,,,,,//S,N,CARDNO $
77  COND     ERROR4,NEIGV $
78  OFP      LAMA,,,,,//S,N,CARDNO $
79  PARAM    //*ADD*/NEVER/1/0 $
80  PARAM    //*MPY*/REPEATE/1/-1 $
81  LABEL    LBL13 $                              Top of Direct Input Matrix Loop
82  PURGE    PHIH,CLAMA,OPHIH,CPHID,CPHIP,QPC,OQPC1,OCPHIP,OESC1,OEFC1,K2PP,
             M2PP,B2PP,K2DD,M2DD,B2DD/NEVER $
83  CASE     CASECC,/CASEXX/*CEIGN*/S,N,REPEATE/S,N,NOLOOP $
84  MTRXIN   CASEXX,MATPOOL,EQDYN,,TFPOOL/K2PP,M2PP,B2PP/LUSETD/S,N,
             NOK2PP/S,N,NOM2PP/S,N,NOB2PP $
85  PURGE    K2DD/NOK2PP/M2DD/NOM2PP/B2DD/NOB2PP $
86  EQUIV    M2PP,M2DD/NOSET/B2PP,B2DD/NOSET/K2PP,K2DD/NOSET $
87  GKAD     USETD,GM,GO,,,,,K2PP,M2PP,B2PP/,,,GMD,GOD,K2DD,M2DD,B2DD/*
             CMPLEV*/*DISP*/*MODAL*/0.0/  0.0/0.0/NOK2PP/NOM2PP/NOB2PP/
             MPCF1/SINGLE/OMIT/NOUE/-1/-1/   -1/-1 $
88  GKAM     USETD,PHIA,MI,LAMA,DIT,M2DD,B2DD,K2DD,CASEXX/MHH,BHH,KHH,PHIDH/
             NOUE/C,Y,LMODES=0/C,Y,LFREQ=0.0/C,Y,HFREQ=-1.0/ NOM2PP/NOB2PP/
             NOK2PP/S,N,NONCUP/S,N,FMODE $
89  CEAD     KHH,BHH,MHH,EED,CASEXX/PHIH,CLAMA,OCEIGS,/S,N,EIGVS $
90  OFP      OCEIGS,,,,,//S,N,CARDNO $
91  COND     LBL17,EIGVS $
92  OFP      CLAMA,,,,,//S,N,CARDNO $
93  VDR      CASEXX,EQDYN,USETD,PHIH,CLAMA,,/OPHIH,/*CEIGEN*/*MODAL*/
             NOSORT2/S,N,NOH/S,N,NOP/FMODE $
94  COND     LBL16,NOH $
95  OFP      OPHIH,,,,,//S,N,CARDNO $
96  LABEL    LBL16 $
97  COND     LBL17,NOP $
98  DDR1     PHIH,PHIDH/CPHID $
```

```
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DISPLACEMENT APPROACH, RIGID FORMAT 10

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

 99  EQUIV    CPHID,CPHIP/NOA $
100  COND     LBLNOA,NOA $
101  SDR1     USETD,,CPHID,,,GOD,GMD,,KFS,,/CPHIP,,QPC/1/*DYNAMICS* $
102  LABEL    LBLNOA $
103  SDR2     CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,,CLAMA,QPC,CPHIP,EST,,/    ,
              OQPC1,OCPHIP,OESC1,OEFC1, /*CEIGEN* $
104  OFP      OCPHIP,OQPC1,OEFC1,OESC1,,//S,N,CARDNO $
105  LABEL    LBL17 $
106  COND     FINIS,REPEATE $
107  REPT     LBL13,100 $                  Bottom of Direct Input Matrix Loop
108  PRTPARM  //-3/*MDLCEAD* $
109  JUMP     FINIS $
110  LABEL    ERROR2 $
111  PRTPARM  //-2/*MDLCEAD* $
112  LABEL    ERROR1 $
113  PRTPARM  //-1/*MDLCEAD* $
114  LABEL    ERROR4 $
115  PRTPARM  //-4/*MDLCEAD* $
116  LABEL    ERROR5 $
117  PRTPARM  //-5/*MDLCEAD* $
118  LABEL    FINIS $
119  PURGE    DUMMY/MINUS1 $
120  END      $
```

3.11.2 Description of DMAP Operations for Modal Complex Eigenvalue Analysis

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

7. GP2 generates Element Connection Table with internal indices.

10. Go to DMAP No. 18 if there are no structure plot requests.

11. PLTSET transforms user input into a form used to drive the structure plotter.

12. PRTMSG prints error messages associated with the structure plotter.

15. Go to DMAP No. 18 if no undeformed structure plots are requested.

16. PLØT generates all requested undeformed structure plots.

17. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

19. GP3 generates Grid Point Temperature Table.

20. TA1 generates element tables for use in matrix assembly and stress recovery.

21. Go to DMAP No. 116 and print Error Message No. 5 if there are no structural elements.

25. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

27. Go to DMAP No. 29 if no stiffness matrix is to be assembled.

28. EMA assembles stiffness matrix $[K^x_{gg}]$ and Grid Point Singularity Table.

30. Go to DMAP No. 112 and print Error Message No. 1 if no mass matrix is to be assembled.

31. EMA assembles mass matrix $[M_{gg}]$.

32. Go to DMAP No. 35 if no weight and balance information is requested.

33. GPWG generates weight and balance information.

34. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

36. Equivalence $[K^x_{gg}]$ to $[K_{gg}]$ if no general elements exist.

37. Go to DMAP No. 39 if no general elements exist.

38. SMA3 adds general elements to $[K^x_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

41. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations $[R_g]\{u_g\} = 0$.

44. Go to DMAP No. 49 if general elements are present.

46. Go to DMAP No. 49 if no potential grid point singularities exist.

47. GPSP generates a table of potential grid point singularities.

48. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

50. Equivalence $[K_{gg}]$ to $[K_{nn}]$ and $[M_{gg}]$ to $[M_{nn}]$ if no multipoint constraints exist.

51. Go to DMAP No. 54 if no multipoint constraints exist.

52. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \quad R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

53. MCE2 partitions stiffness and mass matrices

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right] \quad \text{and} \quad [M_{gg}] = \left[\begin{array}{c|c} \bar{M}_{nn} & M_{nm} \\ \hline M_{mn} & M_{mm} \end{array}\right]$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \quad \text{and}$$

$$[M_{nn}] = [\bar{M}_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m] \quad .$$

55. Equivalence $[K_{nn}]$ to $[K_{ff}]$ and $[M_{nn}]$ to $[M_{ff}]$ if no single-point constraints exist.

56. Go to DMAP No. 58 if no single-point constraints exist.

57. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right] \quad \text{and} \quad [M_{nn}] = \left[\begin{array}{c|c} M_{ff} & M_{fs} \\ \hline M_{sf} & M_{ss} \end{array}\right] .$$

59. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

60. Equivalence $[M_{ff}]$ to $[M_{aa}]$ if no omitted coordinates exist.

61. Go to DMAP No. 64 if no omitted coordinates exist.

62. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right] ,$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

63. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \left[\begin{array}{c|c} \bar{M}_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right]$$

and performs matrix reduction

$$[M_{aa}] = [\bar{M}_{aa}] + [M_{oa}^T][G_o] + [G_o^T][M_{oa}] + [G_o^T][M_{oo}][G_o] .$$

65. Go to DMAP No. 70 if there are no free-body supports.

66. RBMG1 partitions out free-body supports

$$[K_{aa}] = \left[\begin{array}{c|c} K_{\ell\ell} & K_{\ell r} \\ \hline K_{r\ell} & K_{rr} \end{array}\right] \quad \text{and} \quad [M_{aa}] = \left[\begin{array}{c|c} M_{\ell\ell} & M_{\ell r} \\ \hline M_{r\ell} & M_{rr} \end{array}\right] .$$

67. RBMG2 decomposes constrained stiffness matrix $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$.

68. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}],$$

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D]$$

and calculates rigid body error ratio

$$\varepsilon = \frac{||X||}{||K_{rr}||}$$

69. RBMG4 forms rigid body mass matrix

$$[m_r] = [M_{rr}] + [M_{\ell r}^T][D] + [D^T][M_{\ell r}] + [D^T][M_{\ell\ell}][D].$$

71. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating the internal and external grid point numbers (GPLD), including extra points introduced for dynamic analysis (SILD), and prepares Transfer Function Pool (TFPØØL), and Eigenvalue Extraction Data (EED).

72. Go to DMAP No. 110 and print Error Message No. 2 if there is no Eigenvalue Extraction Data.

73. Equivalence $[G_o]$ to $[G_o^d]$ and $[G_m]$ to $[G_m^d]$ if there are no extra points introduced for

dynamic analysis.

75. READ extracts real eigenvalues and eigenvectors from the equation

$$[K_{aa} - \lambda M_{aa}]\{u_a\} = 0 ,$$

calculates rigid body modes by finding a square matrix $[\phi_{ro}]$ such that

$$[m_o] = [\phi_{ro}^T][m_r][\phi_{ro}]$$

is diagonal and normalized, computes rigid body eigenvectors

$$[\phi_{ao}] = \left[\begin{array}{c} D\ \phi_{ro} \\ \hline \phi_{ro} \end{array}\right] ,$$

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calculates modal mass matrix

$$[m] = [\phi_a^T][M_{aa}][\phi_a]$$

and normalizes eigenvectors according to one of the following user requests:

1) Unit value of a selected component
2) Unit value of the largest component
3) Unit value of the generalized mass.

76. ØFP formats the summary of eigenvalue extraction information (ØEIGS) prepared by READ and places it on the system output file for printing.

77. Go to DMAP No. 114 and print Error Message No. 4 if no eigenvalues were found.

78. ØFP formats the eigenvalues (LAMA) prepared by READ and places them on the system output file for printing.

81. Beginning of loop for additional sets of direct input matrices.

83. CASE extracts the appropriate record from CASECC corresponding to the current loop and copies it into CASEXX.

84. MTRXIN selects the direct input matrices for the current loop, $[K^2_{pp}]$, $[M^2_{pp}]$ and $[B^2_{pp}]$.

86. Equivalence $[M^2_{pp}]$ to $[M^2_{dd}]$, $[B^2_{pp}]$ to $[B^2_{dd}]$ and $[K^2_{pp}]$ to $[K^2_{dd}]$ if no constraints are applied.

87. GKAD applies constraints to direct input matrices $[K^2_{pp}]$, $[M^2_{pp}]$ and $[B^2_{pp}]$, forming $[K^2_{dd}]$, $[M^2_{dd}]$ and $[B^2_{dd}]$.

88. GKAM assembles stiffness, mass and damping matrices in modal coordinates for use in Complex Eigenvalue Analysis:

$$[K_{hh}] = [k] + [\phi^T_{dh}][K^2_{dd}][\phi_{dh}] \quad ,$$

$$[M_{hh}] = [m] + [\phi^T_{dh}][M^2_{dd}][\phi_{dh}]$$

and $$[B_{hh}] = [b] + [\phi^T_{dh}][B^2_{dd}][\phi_{dh}] \quad ,$$

where $$m_i = \text{modal masses} \ ,$$

$$b_i = m_i \, 2\pi \, f_i \, g(f_i)$$

and $$k_i = m_i \, 4\pi^2 \, f_i^2 \quad .$$

Direct input matrices may be complex.

89. CEAD extracts complex eigenvalues and eigenvectors from the equation

$$[M_{hh}p^2 + B_{hh}p + K_{hh}] \{u_h\} = 0$$

and normalizes eigenvectors according to one of the following user requests:

1) Unit magnitude of a selected component
2) Unit magnitude of the largest component.

90. ØFP formats the summary of eigenvalue extraction information (ØCEIGS) prepared by CEAD and places it on the system output file for printing.

91. Go to DMAP No. 105 if no complex eigenvalues were found.

92. ØFP formats the complex eigenvalues (CLAMA) prepared by CEAD and places them on the system output file for printing.

93. VDR prepares eigenvectors (ØPHIH) for output, using only the extra points introduced for dynamic analysis and modal coordinates.

94. Go to DMAP No. 96 if there is no output request for the extra points introduced for dynamic analysis or modal coordinates.

95. ØFP formats the table of eigenvectors for extra points introduced for dynamic analysis and modal coordinates prepared by VDR and places it on the system output file for printing.

97. Go to DMAP No. 105 if there is no output request involving dependent degrees of freedom or forces and stresses.

98. DDR1 transforms the complex eigenvectors from modal to physical coordinates

$$[\phi_d] = [\phi_{dh}][\phi_h] \ .$$

99. Equivalence $[\phi_d]$ to $[\phi_p]$ if no constraints are applied.

100. Go to DMAP No. 102 if no constraints are applied.

101. SDR1 recovers dependent components of eigenvectors

$$\{\phi_o\} = [G_o^\phi]\{\phi_d\} \quad , \qquad \begin{Bmatrix} \phi_d \\ \hline \phi_o \end{Bmatrix} = \{\phi_f + \phi_e\} \quad ,$$

$$\begin{Bmatrix} \phi_f + \phi_e \\ \hline \phi_s \end{Bmatrix} = \{\phi_n + \phi_e\} \quad , \qquad \{\phi_m\} = [G_m^d] \ \{\phi_n + \phi_e\} \quad ,$$

$$\begin{Bmatrix} \phi_n + \phi_e \\ \hline \phi_m \end{Bmatrix} = \{\phi_p\}$$

and recovers single-point forces of constraint $\{q_s\} = [K_{fs}^T] \ \{\phi_f\}$.

103. SDR2 calculates element forces (ØEFC1) and stresses (ØESC1) and prepares eigenvectors (ØCPHIP) and single-point forces of constraint (ØQPC1) for output.

104. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

106. Go to DMAP No. 118 and make normal exit if no additional sets of direct input matrices need to be processed.

107. Go to DMAP No. 81 if additional sets of direct input matrices need to be processed.

108. Print Error Message No. 3 and terminate execution.

109. Got to DMAP No. 118 and make normal exit.

111. Print Error Message No. 2 and terminate execution.

113. Print Error Message No. 1 and terminate execution.

115. Print Error Message No. 4 and terminate execution.

117. Print Error Message No. 5 and terminate execution.

3.11.3 Output for Modal Complex Eigenvalue Analysis

The real Eigenvalue Summary Table and the real Eigenvalue Analysis Summary, as described under Normal Mode Analysis (see Section 3.4.3), are automatically printed. All real eigenvalues extracted are included even though not all are used in the modal formulation.

The complex Eigenvalue Summary Table and the complex Eigenvalue Analysis Summary, as described under Direct Complex Eigenvalue Analysis (see Section 3.8.3), are automatically printed for each set of direct input matrices.

Output that may be requested is the same as that described under Direct Complex Eigenvalue Analysis. Output for SØLUTIØN points will have the modal coordinates identified by the mode number determined in real eigenvalue analysis.

The eigenvectors used in the modal formulation may be obtained for the SØLUTIØN points by using the ALTER feature to print the matrix of eigenvectors following the execution of READ. The eigenvectors for all points in the model may be obtained by running the problem initially on the Normal Mode Analysis Rigid Format or by making a modified restart using the Normal Mode Analysis rigid format.

3.11.4 Case Control Deck for Modal Complex Eigenvalue Analysis

The following items related to subcase definition and data selection must be considered in addition to the list presented with Direct Complex Eigenvalue Analysis:

1. METHØD must appear above the subcase level to select an EIGR card that exists in the Bulk Data Deck.
2. All of the eigenvectors used in the modal formulation must be determined in a single execution.
3. An SPC set must be selected above the subcase level unless the model is a free body or all constraints are specified on GRID cards, Scalar Connection cards or with General Elements.
4. SDAMPING must be used to select a TABDMP1 table if structural damping is desired.

3.11.5 Parameters for Modal Complex Eigenvalue Analysis

The following parameters are used in Modal Complex Eigenvalue Analysis:

1. GRDPNT - optional. A positive integer value of this parameter will cause the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
2. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in EMA. Not recommended for use in hydroelastic problems.
3. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters will cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. LFREQ and HFREQ - required unless LMØDES is used. The real values of these parameters give the frequency range (LFREQ is the lower limit and HFREQ is the upper limit) of the modes to be used in the modal formulation.
5. LMØDES - required unless LFREQ and HFREQ are used. The integer value of this parameter is the number of lowest modes to be used in the modal formulation.
6. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
7. AUTØSPC - reserved for future optional use. The default value is -1.

3.11.6 Optional Diagnostic Output for FEER

Special detailed information obtained by requesting DIAG 16 in the Executive Control Deck is the same as that described under Normal Mode Analysis (see Section 3.4.6).

3.11.7 The APPEND Feature

The APPEND feature can be used for real eigenvalue extraction in Modal Complex Eigenvalue Analysis. See Section 3.4.7 for details.

3.11.8 Rigid Format Error Messages from Modal Complex Eigenvalue Analysis

The following fatal errors are detected by the DMAP statements in the Modal Complex Eigenvalue Analysis rigid format. The text for each error message is given below in capital

letters and is followed by additional explanatory material, including suggestions for remedial action.

MØDAL CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 1 - MASS MATRIX REQUIRED FØR MØDAL FØRMULATIØN.

The mass matrix is null because either no structural elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

MØDAL CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 2 - EIGENVALUE EXTRACTIØN DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGR card in the Bulk Data Deck and METHØD in the Case Control Deck must select an EIGR set.

MØDAL CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 3 - ATTEMPT TØ EXECUTE MØRE THAN 100 LØØPS.

An attempt has been made to use more than 100 different sets of direct input matrices. This number can be increased by ALTERing the REPT instruction following the last ØFP instruction.

MØDAL CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 4 - REAL EIGENVALUES REQUIRED FØR MØDAL FØRMULATIØN.

No real eigenvalues were found in the frequency range specified by the user.

MØDAL CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 5 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

3.12 MODAL FREQUENCY AND RANDOM RESPONSE

3.12.1 DMAP Sequence for Modal Frequency and Random Response

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DISPLACEMENT APPROACH, RIGID FORMAT 11

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OPTIONS IN EFFECT   GO     ERR=2    LIST    NODECK  NOREF   NOOSCAR

  1  BEGIN     DISP 11 - MODAL FREQUENCY/RANDOM RESPONSE ANALYSIS-APR. 1984 $
  2  PRECHK    ALL $
  3  FILE      GOD=SAVE/GMD=SAVE/LAMA=APPEND/PHIA=APPEND $
  4  PARAM     //*MPY*/CARDNO/0/0 $
  5  GP1       GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  NOGPDT/
               MINUS1=-1 $
  6  PLTTRAN   BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $
  7  GP2       GEOM2,EQEXIN/ECT $
  8  PARAML    PCDB//*PRES*////JUMPPLOT $
  9  PURGE     PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $
 10  COND      P1,JUMPPLOT $
 11  PLTSET    PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/   S,N,
               JUMPPLOT $
 12  PRTMSG    PLTSETX// $
 13  PARAM     //*MPY*/PLTFLG/1/1 $
 14  PARAM     //*MPY*/PFILE/0/0 $
 15  COND      P1,JUMPPLOT $
 16  PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
               NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $
 17  PRTMSG    PLOTX1// $
 18  LABEL     P1 $
 19  GP3       GEOM3,EQEXIN,GEOM2/,GPTT/NOGRAV $
 20  TA1       ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/LUSET/S,N,NOSIMP/1/
               S,N,NOGENL/S,N,GENEL $
 21  COND      ERROR7,NOSIMP $
 22  PURGE     OGPST/GENEL $
 23  PARAM     //*ADD*/NOKGGX/1/0 $
 24  PARAM     //*ADD*/NOMGG/1/0 $
 25  EMG       EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,/S,N,NOKGGX/ S,
               N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/C,Y,CPQUAD1/C,Y,
               CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/  C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,
               CPTRPLT/C,Y,CPTRBSC $
 26  PURGE     KGGX,GPST/NOKGGX $
 27  COND      JMPKGGX,NOKGGX $
 28  EMA       GPECT,KDICT,KELM/KGGX,GPST $
 29  LABEL     JMPKGGX $
```

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
30  COND    ERROR1,NOMGG $
31  EMA     GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $
32  COND    LGPWG,GRDPNT $
33  GPWG    BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $
34  OFP     OGPWG,,,,,//S,N,CARDNO $
35  LABEL   LGPWG $
36  EQUIV   KGGX,KGG/NOGENL $
37  COND    LBL11,NOGENL $
38  SMA3    GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $
39  LABEL   LBL11 $
40  PARAM   //*MPY*/NSKIP/0/0 $
41  GP4     CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,USET,ASET/ LUSET/
            S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/S,N,NSKIP/S,
            N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/ S,Y,AUTOSPC $
42  PARAM   //*AND*/NOSR/REACT/SINGLE $
43  PURGE   GM,GMD/MPCF1/GO,GOD/OMIT/KFS,PSF/SINGLE/QPC/NOSR/KLR,KRR,MLR,
            MRR,DM,MR/REACT/MDD/MODACC $
44  COND    LBL4,GENEL $
45  PARAM   //*EQ*/GPSPFLG/AUTOSPC/0 $
46  COND    LBL4,GPSPFLG $
47  GPSP    GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
48  OFP     OGPST,,,,,//S,N,CARDNO $
49  LABEL   LBL4 $
50  EQUIV   KGG,KNN/MPCF1/MGG,MNN/MPCF1 $
51  COND    LBL2,MPCF1 $
52  MCE1    USET,RG/GM $
53  MCE2    USET,GM,KGG,MGG,,/KNN,MNN,, $
54  LABEL   LBL2 $
55  EQUIV   KNN,KFF/SINGLE/MNN,MFF/SINGLE $
56  COND    LBL3,SINGLE $
57  SCE1    USET,KNN,MNN,,/KFF,KFS,,MFF,, $
58  LABEL   LBL3 $
59  EQUIV   KFF,KAA/OMIT $
60  EQUIV   MFF,MAA/OMIT $
61  COND    LBL5,OMIT $
62  SMP1    USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
63  SMP2    USET,GO,MFF/MAA $
64  LABEL   LBL5 $
65  EQUIV   KAA,KLL/REACT $
```

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```
66  COND     LBL6,REACT $
67  RBMG1    USET,KAA,MAA/KLL,KLR,KRR,MLL,MLR,MRR $
68  JUMP     LBL8 $
69  LABEL    LBL6 $
70  COND     LBL7,MODACC $
71  LABEL    LBL8 $
72  RBMG2    KLL/LLL $
73  COND     LBL7,REACT $
74  RBMG3    LLL,KLR,KRR/DM $
75  RBMG4    DM,MLL,MLR,MRR/MR $
76  LABEL    LBL7 $
77  DPD      DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPOOL,DLT,PSDL,FRL,,,
             EED,EQDYN/LUSET/S,N,LUSETD/NOTFL/S,N,NODLT/S,N,NOPSDL/  S,N,
             NOFRL/NONLFT/NOTRL/S,N,NOEED//S,N,NOUE $
78  COND     ERROR2,NOEED $
79  PURGE    UEVF/NOUE $
80  EQUIV    GO,GOD/NOUE/GM,GMD/NOUE $
81  PARAM    //*MPY*/NEIGV/1/-1 $
82  READ     KAA,MAA,MR,DM,EED,USET,CASECC/LAMA,PHIA,MI,OEIGS/*MODES*/S,N,
             NEIGV $
83  OFP      OEIGS,,,,,//S,N,CARDNO $
84  COND     ERROR4,NEIGV $
85  OFP      LAMA,,,,,//S,N,CARDNO $
86  PARAM    //*ADD*/NEVER/1/0 $
87  PARAM    //*MPY*/REPEATF/1/-1 $
                                                  Top of Direct Input Matrix Loop
88  LABEL    LBL13 $
89  PURGE    OUHVC1,OUHVC2,XYPLTFA,OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,OPPC2,
             OQPC2,OUPVC2,OESC2,OEFC2,XYPLTF,PSDF,AUTO,XYPLTR,K2PP,M2PP,
             B2PP,K2DD,M2DD,B2DD,OPPCA,IQP1,IPHIP1,IES1,IEF1,OPPC3,IQP2,
             IPHIP2,IES2,IEF2,ZQPC2,ZUPVC2,ZESC2,ZEFC2,ZQPC1,ZUPVC1,ZESC1,
             ZEFC1/NEVER $
90  CASE     CASECC,PSDL/CASEXX/*FREQ*/S,N,REPEATF/S,N,NOLOOP $
91  MTRXIN   CASEXX,MATPOOL,EQDYN,,TFPOOL/K2PP,M2PP,B2PP/LUSETD/S,N,
             NOK2PP/S,N,NOM2PP/S,N,NOB2PP $
92  PURGE    K2DD/NOK2PP/M2DD/NOM2PP/B2DD/NOB2PP $
93  PARAM    //*AND*/MDEMA/NOUE/NOM2PP $
94  EQUIV    M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA/MAA,MDD/MDEMA $
95  GKAD     USETD,GM,GO,,,MAA,,K2PP,M2PP,B2PP/,,MDD,GMD,    GOD,K2DD,M2DD,
             B2DD/*FREQRESP*/*DISP*/*MODAL*/0.0/   0.0/0.0/NOK2PP/NOM2PP/
             NOB2PP/   MPCF1/SINGLE/OMIT/NOUE/-1/-1/   1/V,Y,MODACC = -1 $
96  GKAM     USETD,PHIA,MI,LAMA,DIT,M2DD,B2DD,K2DD,CASEXX/MHH,BHH,KHH,PHIDH/
             NOUE/C,Y,LMODES=0/C,Y,LFREQ=0.0/C,Y,HFREQ=-1.0/ NOM2PP/NOB2PP/
             NOK2PP/S,N,NONCUP/S,N,FMODE $
97  COND     ERROR5,NOFRL $
98  COND     ERROR6,NODLT $
```


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```
 99  FRRD     CASEXX,USETD,DLT,FRL,GMD,GOD,KHH,BHH,MHH,PHIDH,DIT/UHVF,PSF,
              PDF,PPF/*DISP*/*MODAL*/LUSETD/MPCF1/SINGLE/ OMIT/NONCUP/S,N,
              FRQSET $
100  EQUIV    PPF,PDF/NOSET $
101  VDR      CASEXX,EQDYN,USETD,UHVF,PPF,XYCDB,/OUHVC1,/*FREQRESP*/  *MODAL*
              /S,N,NOSORT2/S,N,NOH/S,N,NOP/FMODE $
102  COND     LBL16,NOH $
103  COND     LBL16A,NOSORT2 $
104  SDR3     OUHVC1,,,,,/OUHVC2,,,,, $
105  OFP      OUHVC2,,,,,//S,N,CARDNO $
106  XYTRAN   XYCDB,OUHVC2,,,,/XYPLTFA/*FREQ*/*HSET*/S,N,PFILE/S,N,CARDNO $
107  XYPLOT   XYPLTFA // $
108  JUMP     LBL16 $
109  LABEL    LBL16A $
110  OFP      OUHVC1,,,,,//S,N,CARDNO $
111  LABEL    LBL16 $
112  COND     LBL1[illegible],NOP $
113  PARAM    //*NOT*/NOMOD/V,Y,MODACC $
114  COND     LBDDRM,MODACC $
115  DDR1     UHVF,PHIDH/UDV1F $
116  DDR2     USETD,UDV1F,PDF,K2DD,B2DD,MDD,PPF,LLL,DM/UDV2F,UEVF,PAF/    *
              FREQRESP*/NOUE/REACT/FRQSET $
117  EQUIV    UDV2F,UDV1F/NOMOD $
118  EQUIV    UDV1F,UPVC/NOA $
119  COND     LBLNOA,NOA $
120  SDR1     USETD,,UDV1F,,,GOD,GMD,PSF,KFS,,/UPVC,,QPC/1/*DYNAMICS* $
121  LABEL    LBLNOA $
122  SDR2     CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,BGPDP,PPF,QPC,UPVC,EST,
              XYCDB,PPF/OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,PUGV/*FREQ*/    S,N,
              NOSORT2 $
123  COND     LBL18,NOSORT2 $
124  SDR3     OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,/OPPC2,OQPC2,OUPVC2,OESC2,
              OEFC2, $
125  JUMP     P2A $
126  LABEL    LBDDRM $
127  SDR1     USETD,,PHIDH,,,GOD,GMD,,KFS,,/PHIPH,,QPH/1/*DYNAMICS* $
128  SDR2     CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,,LAMA,QPH,PHIPH,EST,XYCDB,/
              ,IQP1,IPHIP1,IES1,IEF1,/*MMREIG*/S,N,NOSORT2 $
129  SDR2     CASEXX,,,EQDYN,SILD,,,,PPF,,,,XYCDB,PPF/OPPCA,,,,,/*FREQ* $
130  EQUIV    OPPCA,OPPC1/MODACC $
131  COND     LBLSORT,NOSORT2 $
```

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```
132  SDR3     IQP1,IPHIP1,IES1,IEF1,OPPCA,/IQP2,IPHIP2,IES2,IEF2,OPPCB, $
133  EQUIV    OPPCB,OPPC2/MODACC $
134  DDRMM    CASEXX,UHVF,PPF,IPHIP2,IQP2,IES2,IEF2,XYCDB,EST,MPT,DIT/
              ZUPVC2,ZQPC2,ZESC2,ZEFC2, $
135  EQUIV    ZUPVC2,OUPVC2/MODACC/ZQPC2,OQPC2/MODACC/ZESC2,OESC2/MODACC/
              ZEFC2,OEFC2/MODACC $
136  JUMP     P2A $
137  LABEL    LBLSORT $
138  DDRMM    CASEXX,UHVF,PPF,IPHIP1,IQP1,IES1,IEF1,,EST,MPT,DIT/   ZUPVC1,
              ZQPC1,ZESC1,ZEFC1, $
139  EQUIV    ZUPVC1,OUPVC1/MODACC/ZQPC1,OQPC1/MODACC/ZESC1,OESC1/MODACC/
              ZEFC1,OEFC1/MODACC $
140  JUMP     LBL18 $
141  LABEL    P2A $
142  OFP      OPPC2,OQPC2,OUPVC2,OEFC2,OESC2,//S,N,CARDNO $
143  XYTRAN   XYCDB,OPPC2,OQPC2,OUPVC2,OESC2,OEFC2/XYPLTF/*FREQ*/*PSET*/   S,
              N,PFILE/S,N,CARDNO $
144  XYPLOT   XYPLTF// $
145  COND     LBL21,JUMPPLOT $
146  PLOT     PLTPAR,GPSETS,ELSETS,CASEXX,BGPDT,EQEXIN,SIP,,PUGV,,/  PLOTX2/
              NSIL/LUSET/JUMPPLOT/PLTFLG/S,N,PFILE $
147  PRTMSG   PLOTX2// $
148  LABEL    LBL21 $
149  COND     LBL14,NOPSDL $
150  RANDOM   XYCDB,DIT,PSDL,OUPVC2,OPPC2,OQPC2,OESC2,OEFC2,CASEXX/PSDF,AUTO/
              S,N,NORD $
151  COND     LBL14,NORD $
152  XYTRAN   XYCDB,PSDF,AUTO,,,/XYPLTR/*RAND*/*PSET*/S,N,PFILE/   S,N,
              CARDNO $
153  XYPLOT   XYPLTR// $
154  JUMP     LBL14 $
155  LABEL    LBL18 $
156  OFP      OUPVC1,OPPC1,OQPC1,OEFC1,OESC1,//S,N,CARDNO $
157  LABEL    LBL14 $
158  COND     FINIS,REPEATF $
159  REPT     LBL13,100 $              Bottom of Direct Input Matrix Loop
160  PRTPARM  //-3/*MDLFRRD* $
161  JUMP     FINIS $
162  LABEL    ERROR2 $
163  PRTPARM  //-2/*MDLFRRD* $
164  LABEL    ERROR1 $
```

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```
165 PRTPARM //-1/*MDLFRRD* $
166 LABEL   ERROR4 $
167 PRTPARM //-4/*MDLFRRD* $
168 LABEL   ERROR5 $
169 PRTPARM //-5/*MDLFRRD* $
170 LABEL   ERROR6 $
171 PRTPARM //-6/*MDLFRRD* $
172 LABEL   ERROR7 $
173 PRTPARM //-7/*MDLFRRD* $
174 LABEL   FINIS $
175 PURGE   DUMMY/MINUS1 $
176 END     $
```

3.12.2 Description of DMAP Operations for Modal Frequency and Random Response

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

7. GP2 generates Element Connection Table with internal indices.

10. Go to DMAP No. 18 if there are no structure plot requests.

11. PLTSET transforms user input into a form used to drive the structure plotter.

12. PRTMSG prints error messages associated with the structure plotter.

15. Go to DMAP No. 18 if no undeformed structure plots are requested.

16. PLØT generates all requested undeformed structure plots.

17. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

19. GP3 generates Grid Point Temperature Table.

20. TA1 generates element tables for use in matrix assembly and stress recovery.

21. Go to DMAP No. 172 and print Error Message No. 7 if there are no structural elements.

25. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

27. Go to DMAP No. 29 if no stiffness matrix is to be assembled.

28. EMA assembles stiffness matrix $[K^x_{gg}]$ and Grid Point Singularity Table.

30. Go to DMAP No. 164 and print Error Message No. 1 if no mass matrix is to be assembled.

31. EMA assembles mass matrix $[M_{gg}]$.

32. Go to DMAP No. 35 if no weight and balance information is requested.

33. GPWG generates weight and balance information.

34. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

36. Equivalence $[K^x_{gg}]$ to $[K_{gg}]$ if no general elements exist.

37. Go to DMAP No. 39 if no general elements exist.

38. SMA3 adds general elements to $[K^x_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

41. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations $[R_g]\{u_g\} = 0$.

44. Go to DMAP No. 49 if general elements are present.

46. Go to DMAP No. 49 if no potential grid point singularities exist.

47. GPSP generates a table of potential grid point singularities.

48. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

50. Equivalence $[K_{gg}]$ to $[K_{nn}]$ and $[M_{gg}]$ to $[M_{nn}]$ if no multipoint constraints exist.

51. Go to DMAP No. 54 if no multipoint constraints exist.

52. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

53. MCE2 partitions stiffness and mass matrices

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right] \quad \text{and} \quad [M_{gg}] = \left[\begin{array}{c|c} \bar{M}_{nn} & M_{nm} \\ \hline M_{mn} & M_{mm} \end{array}\right]$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \quad \text{and}$$

$$[M_{nn}] = [\bar{M}_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m] \quad .$$

55. Equivalence $[K_{nn}]$ to $[K_{ff}]$ and $[M_{nn}]$ to $[M_{ff}]$ if no single-point constraints exist.

56. Go to DMAP No. 58 if no single-point constraints exist.

57. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right] \quad \text{and} \quad [M_{nn}] = \left[\begin{array}{c|c} M_{ff} & M_{fs} \\ \hline M_{sf} & M_{ss} \end{array}\right] .$$

59. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

60. Equivalence $[M_{ff}]$ to $[M_{aa}]$ if no omitted coordinates exist.

61. Go to DMAP No. 64 if no omitted coordinates exist.

62. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right] ,$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

63. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \left[\begin{array}{c|c} \bar{M}_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right]$$

and performs matrix reduction

$$[M_{aa}] = [\bar{M}_{aa}] + [M_{oa}^T][G_o] + [G_o^T][M_{oa}] + [G_o^T][M_{oo}][G_o] .$$

65. Equivalence $[K_{aa}]$ to $[K_{\ell\ell}]$ if no free-body supports exist.

66. Go to DMAP No. 69 if no free-body supports exist.

67. RBMG1 partitions out free-body supports

$$[K_{aa}] = \left[\begin{array}{c|c} K_{\ell\ell} & K_{\ell r} \\ \hline K_{r\ell} & K_{rr} \end{array}\right] \text{ and } [M_{aa}] = \left[\begin{array}{c|c} M_{\ell\ell} & M_{\ell r} \\ \hline M_{r\ell} & M_{rr} \end{array}\right] .$$

68. Go to DMAP No. 71.

70. Go to DMAP No. 76 if there is no request for mode acceleration data recovery.

72. RBMG2 decomposes constrained stiffness matrix $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$.

73. Go to DMAP No. 76 if no free-body supports exist.

74. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}],$$

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D]$$

and calculates rigid body error ratio

$$\varepsilon = \frac{||X||}{||K_{rr}||} .$$

75. RBMG4 forms rigid body mass matrix

$$[m_r] = [M_{rr}] + [M_{\ell r}^T][D] + [D^T][M_{\ell r}] + [D^T][M_{\ell\ell}][D].$$

77. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating the internal and external grid point numbers (GPLD), including extra points introduced for dynamic analysis (SILD), and prepares Transfer Function Pool (TFPØØL), Dynamic Loads Table (DLT), Power Spectral Density List (PSDL), Frequency Response List (FRL), and Eigenvalue Extraction Data (EED).

78. Go to DMAP No. 162 and print Error Message No. 2 if there is no Eigenvalue Extraction Data.

80. Equivalence $[G_o]$ to $[G_o^d]$ and $[G_m]$ to $[G_m^d]$ if there are no extra points introduced for dynamic analysis.

82. READ extracts real eigenvalues and eigenvectors from the equation

$$[K_{aa} - \lambda M_{aa}]\{u_a\} = 0 ,$$

calculates rigid body modes by finding a square matrix $[\phi_{ro}]$ such that

$$[m_o] = [\phi_{ro}^T][m_r][\phi_{ro}]$$

is diagonal and normalized, computes rigid body eigenvectors

$$[\phi_{ao}] = \left[\begin{array}{c} D\phi_{ro} \\ \hline \phi_{ro} \end{array}\right] ,$$

calculates modal mass matrix

$$[m] = [\phi_a^T][M_{aa}][\phi_a]$$

and normalizes eigenvectors according to one of the following user requests:

1) Unit value of a selected component
2) Unit value of the largest component
3) Unit value of the generalized mass.

83. ØFP formats the summary of eigenvalue extraction information (ØEIGS) prepared by READ and places it on the system output file for printing.

84. Go to DMAP No. 166 and print Error Message No. 4 if no eigenvalues were found.

85. ØFP formats the eigenvalues (LAMA) prepared by READ and places them on the system output file for printing.

88. Beginning of loop for additional sets of direct input matrices.

90. CASE extracts the appropriate record from CASECC corresponding to the current loop and copies it into CASEXX.

91. MTRXIN selects the direct input matrices for the current loop, $[K_{pp}^2]$, $[M_{pp}^2]$ and $[B_{pp}^2]$.

94. Equivalence $[M_{pp}^2]$ to $[M_{dd}^2]$, $[B_{pp}^2]$ to $[B_{dd}^2]$ and $[K_{pp}^2]$ to $[K_{dd}^2]$ if no constraints are applied, and $[M_{aa}]$ to $[M_{dd}]$ if there are no direct input mass matrices and no extra points introduced for dynamic analysis.

95. GKAD applies constraints to direct input matrices $[K_{pp}^2]$, $[M_{pp}^2]$ and $[B_{pp}^2]$, forming $[K_{dd}^2]$, $[M_{dd}^2]$ and $[B_{dd}^2]$.

96. GKAM assembles stiffness, mass and damping matrices in modal coordinates for use in Frequency Response:

$$[K_{hh}] = [k] + [\phi_{dh}^T][K_{dd}^2][\phi_{dh}] ,$$

$$[M_{hh}] = [m] + [\phi_{dh}^T][M_{dd}^2][\phi_{dh}]$$

and

$$[B_{hh}] = [b] + [\phi_{dh}^T][B_{dd}^2][\phi_{dh}] ,$$

where

$$m_i = \text{modal masses} ,$$

$$b_i = m_i \, 2\pi \, f_i \, g(f_i)$$

and $$k_i = m_i 4\pi^2 f_i^2 .$$

Direct input matrices may be complex.

97. Go to DMAP No. 168 and print Error Message No. 5 if there is no Frequency Response List.

98. Go to DMAP No. 170 and print Error Message No. 6 if there is no Dynamic Loads Table.

99. FRRD forms the dynamic load vectors $\{P_h\}$ and solves for the displacements using the following equation

$$[-M_{hh}\omega^2 + iB_{hh}\omega + K_{hh}]\{u_h\} = \{P_h\}.$$

100. Equivalence $\{P_p\}$ to $\{P_d\}$ if no constraints are applied.

101. VDR prepares displacements (ØUHVC1), sorted by frequency, for output using only the extra points introduced for dynamic analysis and modal coordinates (solution points).

102. Go to DMAP No. 111 if there is no output request for solution points.

103. Go to DMAP No. 109 if there is no output request for solution points sorted by extra point or mode number.

104. SDR3 sorts the solution point displacements by extra point or mode number.

105. ØFP formats the requested solution point displacements prepared by SDR3 and places them on the system output file for printing.

106. XYTRAN prepares the input for requested X-Y plots of the solution point displacements vs. frequency.

107. XYPLØT prepares the requested X-Y plots of the solution point displacements vs. frequency.

108. Go to DMAP No. 111.

110. ØFP formats the requested solution point displacements prepared by VDR and places them on the system output file for printing.

112. Go to DMAP No. 157 if there is no output request involving dependent degrees of freedom or forces and stresses.

114. Go to DMAP No. 126 if the mode acceleration technique is not requested.

115. DDR1 transforms the solution vector of displacements from modal to physical coordinates

$$\{u_d\} = [\phi_{dh}]\{u_h\} .$$

116. DDR2 calculates an improved displacement vector using the mode acceleration technique.

117. Equivalence $\{u_d\}$ to the improved displacement vector. (Flag NØMØD is negative since the mode acceleration technique is requested).

118. Equivalence $\{u_d\}$ to $\{u_p\}$ if no constraints are applied.

119. Go to DMAP No. 121 if no constraints are applied.

120. SDR1 recovers dependent components of displacements

$$\{u_o\} = [G_o^d]\{u_a\} \quad , \qquad \begin{Bmatrix} u_d \\ \hline u_o \end{Bmatrix} = \{u_f + u_e\} \quad ,$$

$$\begin{Bmatrix} u_f + u_e \\ \hline u_s \end{Bmatrix} = \{u_n + u_e\} \quad , \qquad \{u_m\} = [G_m^d]\{u_f + u_e\} \quad ;$$

$$\begin{Bmatrix} u_n + u_e \\ \hline u_m \end{Bmatrix} = \{u_p\}$$

and recovers single-point forces of constraint $\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\}$.

122. SDR2 calculates element forces (ØEFC1) and stresses (ØESC1) and prepares load vectors (ØPPC1), displacement vectors (ØUPVC1) and single-point forces of constraint (ØQPC1) for output and translation components of the displacement vector (PUGV), sorted by frequency.

123. Go to DMAP No. 155 if there are no requests for output sorted by point number or element number.

124. SDR3 prepares the requested output sorted by point number of element number.

125. Go to DMAP No. 141.

127. SDR1 recovers dependent components of eigenvectors

$$\{\phi_o\} = [G_o^d]\{\phi_n\} \quad , \qquad \begin{Bmatrix} \phi_n \\ \hline \phi_o \end{Bmatrix} = \{\phi_f + u_e\} \quad ,$$

$$\begin{Bmatrix} \phi_f + u_e \\ \hline \phi_s \end{Bmatrix} = \{\phi_n + u_e\} \quad , \qquad \{\phi_m\} = [G_m^d]\{\phi_n + u_e\} \quad ,$$

$$\begin{Bmatrix} \phi_n + u_e \\ \hline \phi_m \end{Bmatrix} = \{\phi_g + u_e\} = \{\phi_p\}$$

and recovers single-point forces of constraint $\{q_s\} = [K_{fs}]^T\{\phi_f\}$.

128. SDR2 calculates element forces (IEF1) and stresses (IES1) and prepares eigenvectors (IPHIP1) and single-point forces of constraint (IQP1) for output sorted by frequency.

129. SDR2 prepares load vectors for output (ØPPCA) sorted by frequency.

130. Equivalence ØPPCA to ØPPC1. (Flag MØDACC is negative since the mode acceleration technique is not requested).

131. Go to DMAP No. 137 if there are no requests for output sorted by point number or element number.

132. SDR3 prepares the requested output sorted by point number or element number.

133. Equivalence ØPPCB to ØPPC2. (Flag MØDACC is negative since the mode acceleration technique is not requested).

134. DDRMM prepares a subset of the element forces (ZEFC2) and stresses (ZESC2), and displacement vectors (ZUPVC2) and single-point forces of constraint (ZQPC2) for output sorted by point number or element number.

135. Equivalence ZUPVC2 to ØUPVC2, ZQPC2 to ØQPC2, ZESC2 to ØESC2, and ZEFC2 to ØEFC2. (Flag MØDACC is negative since the mode acceleration technique is not requested).

136. Go to DMAP No. 141.

138. DDRMM prepares a subset of the element forces (ZEFC1) and stresses (ZESC1), and displacement vectors (ZUPVC1) and single-point forces of constraint (ZQPC1) for output sorted by frequency.

139. Equivalence ZUPVC1 to ØUPVC1, ZQPC1 to ØQPC1, ZESC1 to ØESC1, and ZEFC1 to ØEFC1. (Flag MØDACC is negative since the mode acceleration technique is not requested).

140. Go to DMAP No. 155.

142. ØFP formats the requested output prepared by SDR3 (with mode acceleration) or DDRMM (no mode acceleration) and places it on the system output file for printing.

143. XYTRAN prepares the input for requested X-Y plots.

144. XYPLØT prepares the requested X-Y plots of displacements, forces, stresses, loads and single-point forces of constraint vs. frequency.

145. Go to DMAP No. 148 if no deformed structure plots are requested.

146. PLØT generates all requested deformed structure and contour plots.

147. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.

149. Go to DMAP No. 157 if no power spectral density functions or autocorrelation functions are requested.

150. RANDØM calculates power spectral density functions (PSDF) and autocorrelation functions (AUTØ) using the previously calculated frequency response.

151. Go to DMAP No. 157 if no X-Y plots of RANDØM calculations are requested.

152. XYTRAN prepares the input for requested X-Y plots of the RANDØM output.

153. XYPLØT prepares the requested X-Y plots of autocorrelation functions and power spectral density functions.

154. Go to DMAP No. 157.

156. ØFP formats the frequency response output requests prepared by SDR2 (with mode acceleration) or DDRMM (no mode acceleration) and places them on the system output file for printing.

158. Go to DMAP No. 174 and make normal exit if no additional sets of direct input matrices need to be processed.

159. Go to DMAP No. 88 if additional sets of direct input matrices need to be processed.

160. Print Error Message No. 3 and terminate execution.

161. Go to DMAP No. 174 and make normal exit.

163. Print Error Message No. 2 and terminate execution.

165. Print Error Message No. 1 and terminate execution.

167. Print Error Message No. 4 and terminate execution.

169. Print Error Message No. 5 and terminate execution.

171. Print Error Message No. 6 and terminate execution.

173. Print Error Message No. 7 and terminate execution.

3.12.3 Output for Modal Frequency and Random Response

The Eigenvalue Summary Table and the Eigenvalue Analysis Summary, as described under Normal Mode Analysis (see Section 3.4.3), are automatically printed. All real eigenvalues extracted are included even though not all are used in the modal formulation.

Output that may be requested is the same as that described under Direct Frequency and Random Response. Output for SØLUTIØN points will have the modal coordinates identified by the mode number determined in real eigenvalue analysis.

The eigenvectors used in the modal formulation may be obtained for the SØLUTIØN points by using the ALTER feature to print the matrix of eigenvectors following the execution of READ. The eigenvectors for all points in the model may be obtained by running the problem initially on the Normal Mode Analysis rigid format or by making a modified restart using the Normal Mode Analysis rigid format.

3.12.4 Case Control Deck for Modal Frequency and Random Response

The following items related to subcase definition and data selection must be considered in addition to the list presented with Direct Frequency and Random Response:

1. METHØD must appear above the subcase level to select an EIGR card that exists in the Bulk Data Deck.
2. All of the eigenvectors used in the modal formulation must be determined in a single execution.
3. An SPC set must be selected above the subcase level unless the model is a free body or all constraints are specified on GRID cards, Scalar Connection cards or with General Elements.
4. SDAMPING must be used to select a TABDMP1 table if structural damping is desired.

3.12.5 Parameters for Modal Frequency and Random Response

The following parameters are used in Modal Frequency and Random Response:

1. GRDPNT - optional. A positive integer value of this parameter will cause the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.

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2. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in EMA. Not recommended for use in hydroelastic problems.

3. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters will cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.

4. LFREQ and HFREQ - required unless LMØDES is used. The real values of these parameters give the frequency range (LFREQ is the lower limit and HFREQ is the upper limit) of the modes to be used in the modal formulation.

5. LMØDES - required unless LFREQ and HFREQ are used. The integer value of this parameter is the number of lowest modes to be used in the modal formulation.

6. MØDACC - optional. A positive integer value of this parameter causes the Dynamic Data Recovery module to use the mode acceleration method. Not recommended for use in hydroelastic problems.

7. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.

8. AUTØSPC - reserved for future optional use. The default value is -1.

3.12.6 Optional Diagnostic Output for FEER

Special detailed information obtained by requesting DIAG 16 in the Executive Control Deck is the same as that described under Normal Mode Analysis (see Section 3.4.6).

3.12.7 The APPEND Feature

The APPEND feature can be used for real eigenvalue extraction in Modal Frequency and Random Response. See Section 3.4.7 for details.

3.12.8 Rigid Format Error Messages from Modal Frequency and Random Response

The following fatal errors are detected by the Modal Frequency and Random Response rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

MØDAL FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 1 - MASS MATRIX REQUIRED FØR MØDAL FØRMULATIØN.

The mass matrix is null because either no structural elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

MØDAL FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 2 - EIGENVALUE EXTRACTIØN DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGR card in the Bulk Data Deck and METHØD in the Case Control Deck must select an EIGR set.

MØDAL FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 3 - ATTEMPT TØ EXECUTE MØRE THAN 100 LØØPS.

An attempt has been made to use more than 100 sets of direct input matrices. This number can be increased by ALTERing the REPT instruction following the last ØFP instruction.

MØDAL FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 4 - REAL EIGENVALUES REQUIRED FØR MØDAL FØRMULATIØN.

No real eigenvalues were found in the frequency range specified by the user.

MØDAL FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 5 - FREQUENCY RESPØNSE LIST REQUIRED FØR FREQUENCY RESPØNSE CALCULATIØNS.

Frequencies to be used in the solution of frequency response problems must be supplied on a FREQ, FREQ1 or FREQ2 card in the Bulk Data Deck and FREQ in the Case Control Deck must select a frequency response set.

MØDAL FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 6 - DYNAMIC LØADS TABLE REQUIRED FØR FREQUENCY RESPØNSE CALCULATIØNS.

Dynamic loads to be used in the solution of frequency response problems must be specified on an RLØAD1 or RLØAD2 card in the Bulk Data Deck and DLØAD in the Case Control Deck must select a dynamic load set.

MØDAL FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 7 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

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3.13 MODAL TRANSIENT RESPONSE

3.13.1 DMAP Sequence for Modal Transient Response

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    LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

OPTIONS IN EFFECT   GO      ERR=2   LIST    NODECK  NOREF   NOOSCAR

  1 BEGIN     DISP 12 - MODAL TRANSIENT RESPONSE ANALYSIS - APR. 1984 $
  2 PRECHK    ALL $
  3 FILE      LAMA=APPEND/PHIA=APPEND/UHVT=APPEND/TOL=APPEND $
  4 PARAM     //*MPY*/CARDNO/0/0 $
  5 GP1       GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  NOGPDT/
              MINUS1=-1 $
  6 PLTTRAN   BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $
  7 GP2       GEOM2,EQEXIN/ECT $
  8 PARAML    PCDB//*PRES*////JUMPPLOT $
  9 PURGE     PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $
 10 COND      P1,JUMPPLOT $
 11 PLTSET    PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/   S,N,
              JUMPPLOT $
 12 PRTMSG    PLTSETX// $
 13 PARAM     //*MPY*/PLTFLG/1/1 $
 14 PARAM     //*MPY*/PFILE/0/0 $
 15 COND      P1,JUMPPLOT $
 16 PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
              NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $
 17 PRTMSG    PLOTX1// $
 18 LABEL     P1 $
 19 GP3       GEOM3,EQEXIN,GEOM2/SLT,GPTT/NOGRAV $
 20 TA1       ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/LUSET/S,N,NOSIMP/1/
              S,N,NOGENL/S,N,GENEL $
 21 COND      ERROR6,NOSIMP $
 22 PURGE     OGPST/GENEL $
 23 PARAM     //*ADD*/NOKGGX/1/0 $
 24 PARAM     //*ADD*/NOMGG/1/0 $
 25 EMG       EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,/S,N,NOKGGX/ S,
              N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/C,Y,CPQUAD1/C,Y,
              CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/  C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,
              CPTRPLT/C,Y,CPTRBSC $
 26 PURGE     KGGX,GPST/NOKGGX $
 27 COND      JMPKGGX,NOKGGX $
 28 EMA       GPECT,KDICT,KELM/KGGX,GPST $
 29 LABEL     JMPKGGX $
```


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```
30  COND     ERROR1,NOMGG $
31  EMA      GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $
32  COND     LGPWG,GRDPNT $
33  GPWG     BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $
34  OFP      OGPWG,,,,,//S,N,CARDNO $
35  LABEL    LGPWG $
36  EQUIV    KGGX,KGG/NOGENL $
37  COND     LBL11,NOGENL $
38  SMA3     GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $
39  LABEL    LBL11 $
40  PARAM    //*MPY*/NSKIP/0/0 $
41  GP4      CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,USET,ASET/ LUSET/
             S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/S,N,NSKIP/S,
             N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/ S,Y,AUTOSPC $
42  PARAM    //*AND*/NOSR/REACT/SINGLE $
43  PURGE    GM,GMD/MPCF1/GO,GOD/OMIT/KFS,PST/SINGLE/QP/NOSR/KLR,KRR,MLR,MR,
             MRR,DM/REACT $
44  COND     LBL4,GENEL $
45  PARAM    //*EQ*/GPSPFLG/AUTOSPC/0 $
46  COND     LBL4,GPSPFLG $
47  GPSP     GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
48  OFP      OGPST,,,,,//S,N,CARDNO $
49  LABEL    LBL4 $
50  EQUIV    KGG,KNN/MPCF1/MGG,MNN/MPCF1 $
51  COND     LBL2,MPCF1 $
52  MCE1     USET,RG/GM $
53  MCE2     USET,GM,KGG,MGG,,/KNN,MNN,, $
54  LABEL    LBL2 $
55  EQUIV    KNN,KFF/SINGLE/MNN,MFF/SINGLE $
56  COND     LBL3,SINGLE $
57  SCE1     USET,KNN,MNN,,/KFF,KFS,,MFF,, $
58  LABEL    LBL3 $
59  EQUIV    KFF,KAA/OMIT $
60  EQUIV    MFF,MAA/OMIT $
61  COND     LBL5,OMIT $
62  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
63  SMP2     USET,GO,MFF/MAA $
64  LABEL    LBL5 $
65  EQUIV    KAA,KLL/REACT $
```


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```
66  COND     LBL6,REACT $
67  RBMG1    USET,KAA,MAA/KLL,KLR,KRR,MLL,MLR,MRR $
68  JUMP     LBL8 $
69  LABEL    LBL6 $
70  COND     LBL7,MODACC $
71  LABEL    LBL8 $
72  RBMG2    KLL/LLL $
73  COND     LBL7,REACT $
74  RBMG3    LLL,KLR,KRR/DM $
75  RBMG4    DM,MLL,MLR,MRR/MR $
76  LABEL    LBL7 $
77  DPD      DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPOOL,DLT,,,NLFT,TRL,
             EED ,EQDYN/LUSET/S,N,LUSETD/NOTFL/S,N,NODLT/NOPSDL/ NOFRL/S,N,
             NONLFT/S,N,NOTRL/S,N,NOEED//S,N,NOUE $
78  COND     ERROR2,NOEED $
79  PURGE    UEVT/NOUE/PNLH/NONLFT $
80  EQUIV    GO,GOD/NOUE/GM,GMD/NOUE $
81  PARAM    //*MPY*/NEIGV/1/-1 $
82  READ     KAA,MAA,MR,DM,EED,USET,CASECC/LAMA,PHIA,MI,OEIGS/*MODES*/S,N,
             NEIGV $
83  OFP      OEIGS ,,,,//S,N,CARDNO $
84  COND     ERROR4,NEIGV $
85  OFP      LAMA,,,,,//S,N,CARDNO $
86  MTRXIN   CASECC,MATPOOL,EQDYN,,TFPOOL/K2PP,M2PP,B2PP/LUSETD/S,N,
             NOK2PP/S,N,NOM2PP/S,N,NOB2PP $
87  PURGE    K2DD/NOK2PP/M2DD/NOM2PP/B2DD/NOB2PP $
88  PARAM    //*AND*/MDEMA/NOUE/NOM2PP $
89  EQUIV    M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA/MAA,MDD/MDEMA $
90  GKAD     USETD,GM,GO,,,MAA,,K2PP,M2PP,B2PP/,,MDD,GMD,   GOD,K2DD,M2DD,
             B2DD/*TRANRESP*/*DISP*/*MODAL*/0.0/   0.0/0.0/NOK2PP/NOM2PP/
             NOB2PP/   MPCF1/SINGLE/OMIT/NOUE/-1/-1/   1/V,Y,MODACC = -1 $
91  GKAM     USETD,PHIA,MI,LAMA,DIT,M2DD,B2DD,K2DD,CASECC/MHH,BHH,KHH,PHIDH/
             NOUE/C,Y,LMODES=0/C,Y,LFREQ=0.0/C,Y,HFREQ=-1.0/ NOM2PP/NOB2PP/
             NOK2PP/S,N,NONCUP/S,N,FMODE $
92  COND     ERROR5,NOTRL $
93  PARAM    //*ADD*/NEVER/1/0 $
94  PARAM    //*MPY*/REPEATT/1/-1 $
95  LABEL    LBL13 $                          Top of Dynamic Load Set Loop
96  PURGE    PNLH,OUHV1,OPNL1,OUHV2,OPNL2,XYPLTTA,OPP1,OQP1,OUPV1,OES1,OEF1,
             OPP2,OQP2,OUPV2,OES2,OEF2,PLOTX2,XYPLTT,OPPA,IQP1,IPHIP1,IES1,
             IEF1,OPPB,IQP2,IPHIP2,IES2,IEF2,ZQP2,ZUPV2,ZES2,ZEF2/NEVER $
97  CASE     CASECC,/CASEXX/*TRAN*/S,N,REPEATT/S,N,NOLOOP $
```


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```
 98 PARAM    //*MPY*/NCOL/0/1 $
 99 TRLG     CASEXX,USETD,DLT,SLT,BGPDT,SIL,CSTM,TRL,DIT,GMD,GOD,PHIDH, EST,
             MGG/PPT,PST,PDT,PD,PH,TOL/S,N,NOSET/NCOL $
100 EQUIV    PPT,PDT/NOSET $
101 TRD      CASEXX,TRL,NLFT,DIT,KHH,BHH,MHH,PH/UHVT,PNLH/*MODAL*/   NOUE/
             NONCUP/S,N,NCOL/C,Y,ISTART $
102 VDR      CASEXX,EQDYN,USETD,UHVT,TOL,XYCDB,PNLH/OUHV1,OPNL1/ *TRANRESP*/
             *MODAL*/0/S,N,NOH/S,N,NOP/FMODE $
103 COND     LBL16,NOH $
104 SDR3     OUHV1,OPNL1,,,,/OUHV2,OPNL2,,,, $
105 OFP      OUHV2,OPNL2,,,,//S,N,CARDNO $
106 XYTRAN   XYCDB,OUHV2,OPNL2,,,/XYPLTTA/*TRAN*/*HSET*/S,N,PFILE/S,N,
             CARDNO $
107 XYPLOT   XYPLTTA// $
108 LABEL    LBL16 $
109 PARAM    //*AND*/PJUMP/NOP/JUMPPLOT $
110 COND     LBL15,PJUMP $
111 PARAM    //*NOT*/NOMOD/V,Y,MODACC $
112 PARAM    //*AND*/MPJUMP/V,Y,MODACC/JUMPPLOT $
113 COND     LBDDRM,MPJUMP $
114 DDR1     UHVT,PHIDH/UDV1T $
115 COND     LBLMOD,MODACC $
116 DDR2     USETD,UDV1T,PDT,K2DD,B2DD,MDD,,LLL,DM/UDV2T,UEVT,PAF/  *
             TRANRESP*/NOUE/REACT/0 $
117 EQUIV    UDV2T,UDV1T/NOMOD $
118 LABEL    LBLMOD $
119 EQUIV    UDV1T,UPV/NOA $
120 COND     LBL14,NOA $
121 SDR1     USETD,,UDV1T,,,GOD,GMD,PST,KFS,,/UPV,,QP/1/*DYNAMICS* $
122 LABEL    LBL14 $
123 SDR2     CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,BGPDP,TOL,QP,UPV,EST,XYCDB,
             PPT/OPP1,OQP1,OUPV1,OES1,OEF1,PUGV/*TRANRESP* $
124 SDR3     OPP1,OQP1,OUPV1,OES1,OEF1,/OPP2,OQP2,OUPV2,OES2,OEF2, $
125 JUMP     P2A $
126 LABEL    LBDDRM $
127 SDR1     USETD,,PHIDH,,,GOD,GMD,,KFS,,/PHIPH,,QPH/1/*DYNAMICS* $
128 SDR2     CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,,LAMA,QPH,PHIPH,EST,XYCDB,/
             ,IQP1,IPHIP1,IES1,IEF1,/*MMREIG* $
129 SDR2     CASEXX,,,,EQDYN,SILD,,,,TOL,,,,XYCDB,PPT/OPPA,,,,,/*TRANRESP* $
130 SDR3     OPPA,IQP1,IPHIP1,IES1,IEF1,/OPPB,IQP2,IPHIP2,IES2,IEF2, $
```


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```
131  EQUIV    OPPB,OPP2/MODACC $
132  DDRMM    CASEXX,UHVT,TOL,IPHIP2,IQP2,IES2,IEF2,,EST,MPT,DIT/    ZUPV2,
              ZQP2,ZES2,ZEF2, $
133  EQUIV    ZUPV2,OUPV2/MODACC/ZQP2,OQP2/MODACC/ZEF2,OEF2/MODACC/ZES2,OES2/
              MODACC $
134  LABEL    P2A $
135  OFP      OUPV2,OPP2,OQP2,OEF2,OES2,//S,N,CARDNO $
136  COND     P2,JUMPPLOT $
137  PLOT     PLTPAR,GPSETS,ELSETS,CASEXX,BGPDT,EQEXIN,SIP,,PUGV,,/PLOTX2/
              NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $
138  PRTMSG   PLOTX2// $
139  LABEL    P2 $
140  XYTRAN   XYCDB,OPP2,OQP2,OUPV2,OES2,OEF2/XYPLTT/*TRAN*/*PSET*/S,N,PFILE/
              S,N,CARDNO $
141  XYPLOT   XYPLTT// $
142  LABEL    LBL15 $
143  COND     FINIS,REPEATT $
144  REPT     LBL13,100 $                          Bottom of Dynamic Load Set Loop
145  PRTPARM  //-3/*MDLTRD* $
146  JUMP     FINIS $
147  LABEL    ERROR2 $
148  PRTPARM  //-2/*MDLTRD* $
149  LABEL    ERROR1 $
150  PRTPARM  //-1/*MDLTRD* $
151  LABEL    ERROR4 $
152  PRTPARM  //-4/*MDLTRD* $
153  LABEL    ERROR5 $
154  PRTPARM  //-5/*MDLTRD* $
155  LABEL    ERROR6 $
156  PRTPARM  //-6/*MDLTRD* $
157  LABEL    FINIS $
158  PURGE    DUMMY/MINUS1 $
159  END      $
```


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3.13.2 Description of DMAP Operations for Modal Transient Response

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

7. GP2 generates Element Connection Table with internal indices.

10. Go to DMAP No. 18 if there are no structure plot requests.

11. PLTSET transforms user input into a form used to drive the structure plotter.

12. PRTMSG prints error messages associated with the structure plotter.

15. Go to DMAP No. 18 if no undeformed structure plots are requested.

16. PLØT generates all requested undeformed structure plots.

17. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

19. GP3 generates Grid Point Temperature Table.

20. TA1 generates element tables for use in matrix assembly and stress recovery.

21. Go to DMAP No. 155 and print Error Message No. 6 if there are no structural elements.

25. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

27. Go to DMAP No. 29 if no stiffness matrix is to be assembled.

28. EMA assembles stiffness matrix $[K^x_{gg}]$ and Grid Point Singularity Table.

30. Go to DMAP No. 149 and print Error Message No. 1 if no mass matrix is to be assembled.

31. EMA assembles mass matrix $[M_{gg}]$.

32. Go to DMAP No. 35 if no weight and balance information is requested.

33. GPWG generates weight and balance information.

34. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

36. Equivalence $[K^x_{gg}]$ to $[K_{gg}]$ if no general elements exist.

37. Go to DMAP No. 39 if no general elements exist.

38. SMA3 adds general elements to $[K^x_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

41. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations $[R_g] \{u_g\} = 0$.

44. Go to DMAP No. 49 if general elements are present.

46. Go to DMAP No. 49 if no potential grid point singularities exist.

47. GPSP generates a table of potential grid point singularities.

48. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

50. Equivalence $[K_{gg}]$ to $[K_{nn}]$ and $[M_{gg}]$ to $[M_{nn}]$ if no multipoint constraints exist.

51. Go to DMAP No. 54 if no multipoint constraints exist.

52. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

53. MCE2 partitions stiffness and mass matrices

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right] \quad \text{and} \quad [M_{gg}] = \left[\begin{array}{c|c} \bar{M}_{nn} & M_{nm} \\ \hline M_{mn} & M_{mm} \end{array}\right]$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \quad \text{and}$$

$$[M_{nn}] = [\bar{M}_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m] \quad .$$

55. Equivalence $[K_{nn}]$ to $[K_{ff}]$ and $[M_{nn}]$ to $[M_{ff}]$ if no single-point constraints exist.

56. Go to DMAP No. 58 if no single-point constraints exist.

57. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right] \quad \text{and} \quad [M_{nn}] = \left[\begin{array}{c|c} M_{ff} & M_{fs} \\ \hline M_{sf} & M_{ss} \end{array}\right] .$$

59. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

60. Equivalence $[M_{ff}]$ to $[M_{aa}]$ if no omitted coordinates exist.

61. Go to DMAP No. 64 if no omitted coordinates exist.

62. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right] ,$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

63. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \left[\begin{array}{c|c} \bar{M}_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right]$$

and performs matrix reduction

$$[M_{aa}] = [\bar{M}_{aa}] + [M_{oa}^T][G_o] + [G_o^T][M_{oa}] + [G_o^T][M_{oo}][G_o] \ .$$

65. Equivalence $[K_{aa}]$ to $[K_{\ell\ell}]$ if no free-body supports exist.

66. Go to DMAP No. 69 if no free-body supports exist.

67. RBMG1 partitions out free-body supports

$$[K_{aa}] = \left[\begin{array}{c|c} K_{\ell\ell} & K_{\ell r} \\ \hline K_{r\ell} & K_{rr} \end{array}\right] \text{ and } \qquad [M_{aa}] = \begin{array}{c|c} M_{\ell\ell} & M_{\ell r} \\ \hline M_{r\ell} & M_{rr} \end{array} \ .$$

68. Go to DMAP No. 71.

70. Go to DMAP No. 76 if there is no request for mode acceleration data recovery.

72. RBMG2 decomposes constrained stiffness matrix $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$.

73. Go to DMAP No. 76 if no free-body supports exist.

74. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}],$$

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D]$$

and calculates rigid body error ratio

$$\varepsilon = \frac{||X||}{||K_{rr}||} \ .$$

75. RBMG4 forms rigid body mass matrix

$$[m_r] = [M_{rr}] + [M_{\ell r}^T][D] + [D^T][M_{\ell r}] + [D^T][M_{\ell\ell}][D].$$

77. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating the internal and external grid point numbers (GPLD), including extra points introduced for dynamic analysis (SILD), and prepares Transfer Function Pool (TFPØØL), Dynamic Loads Table (DLT), Nonlinear Function Table (NLFT), Transient Response List (TRL).

78. Go to DMAP No. 147 and print Error Message No. 2 if there is no Eigenvalue Extraction Data.

80. Equivalence $[G_o]$ to $[G_o^d]$ and $[G_m]$ to $[G_m^d]$ if there are no extra points introduced for dynamic analysis.

82. READ extracts real eigenvalues and eigenvectors from the equation

$$[K_{aa} - \lambda M_{aa}]\{u_a\} = 0 \ ,$$

calculates rigid body modes by finding a square matrix $[\phi_{ro}]$ such that

$$[m_o] = [\phi_{ro}^T][m_r][\phi_{ro}]$$

is diagonal and normalized, computes rigid body eigenvectors

$$[\phi_{ao}] = \left[\frac{D\phi_{ro}}{\phi_{ro}}\right] ,$$

calculates modal mass matrix

$$[m] = [\phi_a^T][M_{aa}][\phi_a]$$

and normalizes eigenvectors according to one of the following user requests:

1) Unit value of a selected component
2) Unit value of the largest component
3) Unit value of the generalized mass.

83. ØFP formats the summary of eigenvalue extraction information (ØEIGS) prepared by READ and places it on the system output file for printing.

84. Go to DMAP No. 151 and print Error Message No. 4 if no eigenvalues were found.

85. ØFP formats the eigenvalues (LAMA) prepared by READ and places them on the system output file for printing.

86. MTRXIN selects the direct input matrices $[K_{pp}^2]$, $[M_{pp}^2]$ and $[B_{pp}^2]$.

89. Equivalence $[M_{pp}^2]$ to $[M_{dd}^2]$, $[B_{pp}^2]$ to $[B_{dd}^2]$ and $[K_{pp}^2]$ to $[K_{dd}^2]$ if no constraints are applied, and $[M_{aa}]$ to $[M_{dd}]$ if there are no direct input mass matrices and no extra points introduced for dynamic analysis.

90. GKAD applies constraints to direct input matrices $[K_{pp}^2]$, $[M_{pp}^2]$ and $[B_{pp}^2]$, forming $[K_{dd}^2]$, $[M_{dd}^2]$ and $[B_{dd}^2]$.

91. GKAM assembles stiffness, mass and damping matrices in modal coordinates for use in Transient Response:

$$[K_{hh}] = [k] + [\phi_{dh}^T][K_{dd}^2][\phi_{dh}] ,$$

$$[M_{hh}] = [m] + [\phi_{dh}^T][M_{dd}^2][\phi_{dh}]$$

and $$[B_{hh}] = [b] + [\phi_{dh}^T][B_{dd}^2][\phi_{dh}] ,$$

where m_i = modal masses ,

$b_i = m_i \, 2\pi \, f_i \, g(f_i)$

and $k_i = m_i \, 4\pi^2 \, f_i^2$.

All matrices are real.

92. Go to DMAP No. 153 and print Error Message No. 5 if there is no Transient Response List.

95. Beginning of loop for additional dynamic load sets.

97. CASE extracts the appropriate record from CASECC corresponding to the current loop and copies it into CASEXX.

99. TRLG generates matrices of loads versus time. $\{P_p^t\}$, $\{P_s^t\}$ and $\{P_d^t\}$ are generated with one column per output time step. $\{P_d\}$ and $\{P_h\}$ are generated with one column per solution time step, and the Transient Output List (TØL) is a list of output time steps.

100. Equivalence $\{P_d^t\}$ to $\{P_p^t\}$ if the d and p sets are the same.

101. TRD forms the linear, $\{P_d\}$, and nonlinear, $\{P_d^{n\ell}\}$, dynamic load vectors and integrates the equations of motion over specified time periods to solve for the displacements, velocities and accelerations, using the following equation

$$[M_{hh}p^2 + B_{hh}p + K_{hh}]\{u_h\} = \{P_h\} + \{P_h^{n\ell}\} \ .$$

102. VDR prepares displacements, velocities and accelerations, sorted by time step, for output using only the extra points introduced for dynamic analysis and modal coordinates (solution points).

103. Go to DMAP No. 108 if there is no output request for the solution points.

104. SDR3 sorts the solution point displacements, velocities, accelerations and nonlinear load vectors by extra point or mode number.

105. ØFP formats the requested solution point displacements, velocities, accelerations and nonlinear load vectors prepared by SDR3 and places them on the system output file for printing.

106. XYTRAN prepares the input for X-Y plotting of the solution point displacements, velocities, accelerations and nonlinear load vectors vs. time.

107. XYPLØT prepares the requested X-Y plots of the solution point displacements, velocities, accelerations and nonlinear load vectors vs. time.

110. Go to DMAP No. 142 if there is no output request involving dependent degrees of freedom, forces and stresses, or deformed structure plots.

113. Go to DMAP No. 126 if the mode acceleration technique is not requested and if there are no requests for deformed structure plots.

114. DDR1 transforms the solution vector displacements from modal to physical coordinates

$$\{u_d\} = [\phi_{dh}]\{u_h\} \ .$$

115. Go to DMAP No. 118 if the mode acceleration technique is not requested.

116. DDR2 calculates an improved displacement vector using the mode acceleration technique.

117. Equivalence $\{u_d\}$ to the improved displacement vector. (Flag NØMØD is negative since the mode acceleration technique is requested).

119. Equivalence $\{u_d\}$ to $\{u_p\}$ if no constraints are applied.

120. Go to DMAP No. 122 if no constraints are applied.

121. SDR1 recovers dependent components of displacements

$$\{u_o\} = [G_o^d]\{u_d\} \quad , \qquad \begin{Bmatrix} u_d \\ \hline u_o \end{Bmatrix} = \{u_f + u_e\} \quad ,$$

$$\begin{Bmatrix} u_f + u_e \\ \hline u_s \end{Bmatrix} = \{u_n + u_e\} \quad , \qquad \{u_m\} = [G_m^d]\{u_f + u_e\} \quad ,$$

$$\begin{Bmatrix} u_n + u_e \\ \hline u_m \end{Bmatrix} = \{u_p\}$$

and recovers single-point forces of constraint $\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\}$.

123. SDR2 calculates element forces (ØEF1) and stresses (ØES1) and prepares load vectors (ØPP1), displacement, velocity and acceleration vectors (ØUPV1) and single-point forces of constraint (ØQP1) for output and translation components of the displacement vector (PUGV), sorted by time step.

124. SDR3 prepares requested output sorted by point number or element number.

125. Go to DMAP No. 134.

127. SDR1 recovers dependent components of eigenvectors

$$\{\phi_o\} = [G_o^d]\{\phi_n\} \quad , \qquad \begin{Bmatrix} \phi_h \\ \hline \phi_o \end{Bmatrix} = \{\phi_f + u_e\} \quad ,$$

$$\begin{Bmatrix} \phi_f + u_e \\ \hline \phi_s \end{Bmatrix} = \{\phi_n + \phi_e\} \quad , \qquad \{\phi_m\} = [G_m^d]\{\phi_n + u_e\} \quad ,$$

$$\begin{Bmatrix} \phi_n + u_e \\ \hline \phi_m \end{Bmatrix} = \{\phi_g + u_e\} = \{\phi_p\}$$

and recovers single-point forces of constraint $\{q_s\} = [K_{fs}]^T\{\phi_f\}$.

128. SDR2 calculates element forces (IEF1) and stresses (IES1) and prepares eigenvectors (IPHIP1) and single-point forces of constraint (IQP1) for output sorted by time step.

129. SDR2 prepares load vectors for output (ØPPA) sorted by time step.

130. SDR3 prepares the requested output sorted by point number or element number.

131. Equivalence ØPPB to ØPP2. (Flag MØDACC is negative since the mode acceleration technique is not requested).

132. DDRMM prepares a subset of the element forces (ZEF2) and stresses (ZES2), and displacement vectors (ZUPV2) and single-point forces of constraint (ZQP2) for output sorted by point number or element number.

133. Equivalence ZUPV2 to ØUPV2, ZQP2 to ØQP2, ZES2 to ØES2 and ZEF2 to ØEF2. (Flag MØDACC is negative since the mode acceleration technique is not requested).

135. ØFP formats the requested output prepared by SDR3 (with mode acceleration) or DDRMM (no mode acceleration) and places it on the system output file for printing.

136. Go to DMAP No. 139 if no deformed structure plots are requested.

137. PLØT prepares all requested deformed structure and contour plots.

138. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.

140. XYTRAN prepares the input for requested X-Y plots.

141. XYPLØT prepares the requested X-Y plots of displacements, velocities, accelerations, forces, stresses, loads and single-point forces of constraint vs. time.

143. Go to DMAP No. 157 and make normal exit if no additional dynamic load sets need to be processed.

144. Go to DMAP No. 95 if additional dynamic load sets need to be processed.

145. Print Error Message No. 3 and terminate execution.

146. Go to DMAP No. 157 and make normal exit.

148. Print Error Message No. 2 and terminate execution.

150. Print Error Message No. 1 and terminate execution.

152. Print Error Message No. 4 and terminate execution.

154. Print Error Message No. 5 and terminate execution.

156. Print Error Message No. 6 and terminate execution.

3.13.3 Output for Modal Transient Response

The Eigenvalue Summary Table and the Eigenvalue Analysis Summary, as described under Normal Mode Analysis (see Section 3.4.3), are automatically printed. All real eigenvalues extracted are included even though not all are used in the modal formulation.

Output that may be requested is the same as that described under Direct Transient Response. Output for SØLUTIØN points will have the modal coordinates identified by the mode number determined in real eigenvalue analysis.

The eigenvectors used in the modal formulation may be obtained for the SØLUTIØN points by using the ALTER feature to print the matrix of eigenvectors following the execution of READ. The eigenvectors for all points in the model may be obtained by running the problem initially on the Normal Mode Analysis rigid format or by making a modified restart using the Normal Mode Analysis rigid format.

3.13.4 Case Control Deck for Modal Transient Response

The following items related to subcase definition and data selection must be considered in addition to the list presented with Direct Transient Response:

1. METHØD must appear above the subcase level to select an EIGR card that exists in the Bulk Data Deck.
2. All of the eigenvectors used in the modal formulation must be determined in a single execution.
3. An SPC set must be selected above the subcase level unless the model is a free body or all constraints are specified on GRID cards, Scalar Connection cards or with General Elements.
4. SDAMPING must be used to select a TABDMP1 table if structural damping is desired.

3.13.5 Parameters for Modal Transient Response

The following parameters are used in Modal Transient Response:

1. GRDPNT - optional. A positive integer value of this parameter will cause the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.

2. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in EMA. Not recommended for use in hydroelastic problems.

3. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters will cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.

4. LFREQ and HFREQ - required unless LMØDES is used. The real values of these parameters give the frequency range (LFREQ is the lower limit and HFREQ is the upper limit) of the modes to be used in the modal formulation.

5. LMØDES - required unless LFREQ and HFREQ are used. The integer value of this parameter is the number of lowest modes to be used in the modal formulation.

6. MØDACC - optional. A positive integer value of this parameter causes the Dynamic Data Recovery module to use the mode acceleration method. Not recommended for use in hydroelastic problems.

7. ISTART - optional. A positive value of this parameter will cause the TRD module to use the second (or alternate) starting method (see Section 11.4 of the Theoretical Manual). The alternate starting method is recommended when initial accelerations are significant and when the mass matrix is non-singular.

8. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.

9. AUTØSPC - reserved for future optional use. The default value is -1.

3.13.6 Optional Diagnostic Output for FEER

Special detailed information obtained by requesting DIAG 16 in the Executive Control Deck is the same as that described under Normal Mode Analysis (see Section 3.4.6).

3.13.7 The APPEND Feature

The APPEND feature can be used for real eigenvalue extraction in Modal Transient Response. See Section 3.4.7 for details.

3.13.8 The CONTINUE Feature

The CONTINUE feature can be used for coupled transient analysis in Modal Transient Response. See Section 3.10.6 for details.

3.13.9 Rigid Format Error Messages from Modal Transient Response

The following fatal errors are detected by the DMAP statements in the Modal Transient Response rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

MØDAL TRANSIENT RESPØNSE ERRØR MESSAGE NØ. 1 - MASS MATRIX REQUIRED FØR MØDAL FØRMULATION.

The mass matrix is null because either no structural elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

MØDAL TRANSIENT RESPØNSE ERRØR MESSAGE NØ. 2 - EIGENVALUE EXTRACTIØN DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGR card in the Bulk Data Deck and METHØD in the Case Control Deck must select an EIGR set.

MØDAL TRANSIENT RESPØNSE ERRØR MESSAGE NØ. 3 - ATTEMPT TØ EXECUTE MØRE THAN 100 LØØPS.

An attempt has been made to use more than 100 dynamic load sets. This number can be increased by ALTERing the REPT instruction following the last XYPLØT instruction.

MØDAL TRANSIENT RESPØNSE ERRØR MESSAGE NØ. 4 - REAL EIGENVALUES REQUIRED FØR MØDAL FØRMULATIØN.

No real eigenvalues were found in the frequency range specified by the user.

MØDAL TRANSIENT RESPØNSE ERRØR MESSAGE NØ. 5 - TRANSIENT RESPØNSE LIST REQUIRED FØR TRANSIENT RESPØNSE CALCULATIØNS.

Time step intervals to be used must be specified on a TSTEP card in the Bulk Data Deck and a TSTEP selection must be made in the Case Control Deck.

MØDAL TRANSIENT RESPØNSE ERRØR MESSAGE NØ. 6 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

3.14 NORMAL MODES WITH DIFFERENTIAL STIFFNESS

3.14.1 DMAP Sequence for Normal Modes with Differential Stiffness

```
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DISPLACEMENT APPROACH, RIGID FORMAT 13

    LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

OPTIONS IN EFFECT   GO      ERR=2   LIST    NODECK  NOREF   NOOSCAR
-----------------

   1  BEGIN     DISP 13 - NORMAL MODES WITH DIFFERENTIAL STIFFNESS-APR. 1984 $
   2  PRECHK    ALL $
   3  FILE      LAMA=APPEND/PHIA=APPEND $
   4  PARAM     //*MPY*/CARDNO/0/0 $
   5  GP1       GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  NOGPDT/
                MINUS1=-1 $
   6  PLTTRAN   BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $
   7  GP2       GEOM2,EQEXIN/ECT $
   8  PARAML    PCDB//*PRES*////JUMPPLOT $
   9  PURGE     PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $
  10  COND      P1,JUMPPLOT $
  11  PLTSET    PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/   S,N,
                JUMPPLOT $
  12  PRTMSG    PLTSETX// $
  13  PARAM     //*MPY*/PLTFLG/1/1 $
  14  PARAM     //*MPY*/PFILE/0/0 $
  15  COND      P1,JUMPPLOT $
  16  PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
                NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $
  17  PRTMSG    PLOTX1// $
  18  LABEL     P1 $
  19  GP3       GEOM3,EQEXIN,GEOM2/SLT,GPTT/NOGRAV $
  20  TA1       ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/LUSET/S,N,NOSIMP/1/
                S,N,NOGENL/S,N,GENEL $
  21  COND      ERROR1,NOSIMP $
  22  PURGE     OGPST/GENEL $
  23  PARAM     //*ADD*/NOKGGX/1/0 $
  24  PARAM     //*ADD*/NOMGG/1/0 $
  25  EMG       EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,/S,N,NOKGGX/ S,
                N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/C,Y,CPQUAD1/C,Y,
                CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/  C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,
                CPTRPLT/C,Y,CPTRBSC $
  26  PURGE     KGGX,GPST/NOKGGX $
  27  COND      JMPKGG,NOKGGX $
  28  EMA       GPECT,KDICT,KELM/KGGX,GPST $
  29  LABEL     JMPKGG $
```

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```
30  COND     ERROR5,NOMGG $
31  EMA      GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $
32  COND     LBL1,GRDPNT $
33  GPWG     BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT/C,Y,WTMASS $
34  OFP      OGPWG,,,,,//S,N,CARDNO $
35  LABEL    LBL1 $
36  EQUIV    KGGX,KGG/NOGENL $
37  COND     LBL11,NOGENL $
38  SMA3     GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $
39  LABEL    LBL11 $
40  PARAM    //*MPY*/NSKIP/0/0 $
41  GP4      CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,YS,USET,ASET/
             LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/S,N,
             NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/ S,Y,
             AUTOSPC $
42  COND     ERROR6,NOL $
43  PARAM    //*AND*/NOSR/SINGLE/REACT $
44  PURGE    GM/MPCF1/GO,KOO,LOO,PO,UOOV,RUOV/OMIT/PS,KFS,KSS/SINGLE/  QG/
             NOSR $
45  COND     LBL4D,REACT $
46  JUMP     ERROR2 $
47  LABEL    LBL4D $
48  COND     LBL4,GENEL $
49  PARAM    //*EQ*/GPSPFLG/AUTOSPC/0 $
50  COND     LBL4,GPSPFLG $
51  GPSP     GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
52  OFP      OGPST,,,,,//S,N,CARDNO $
53  LABEL    LBL4 $
54  EQUIV    KGG,KNN/MPCF1 $
55  COND     LBL2,MPCF1 $
56  MCE1     USET,RG/GM $
57  MCE2     USET,GM,KGG,,,/KNN,,, $
58  LABEL    LBL2 $
59  EQUIV    KNN,KFF/SINGLE $
60  COND     LBL3,SINGLE $
61  SCE1     USET,KNN,,,/KFF,KFS,KSS,,, $
62  LABEL    LBL3 $
63  EQUIV    KFF,KAA/OMIT $
64  COND     LBL5,OMIT $
```

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```
65  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
66  LABEL    LBL5 $
67  RBMG2    KAA/LLL $
68  SSG1     SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,CASECC,DIT,/PG,,,,/
             LUSET/1 $
69  EQUIV    PG,PL/NOSET $
70  COND     LBL10,NOSET $
71  SSG2     USET,GM,YS,KFS,GO,,PG/,PO,PS,PL $
72  LABEL    LBL10 $
73  SSG3     LLL,KAA,PL,LOO,KOO,PO/ULV,UOOV,RULV,RUOV/OMIT/V,Y,IRES=-1/ 1/S,
             N,EPSI $
74  COND     LBL9,IRES $
75  MATGPR   GPL,USET,SIL,RULV//*L* $
76  MATGPR   GPL,USET,SIL,RUOV//*O* $
77  LABEL    LBL9 $
78  SDR1     USET,PG,ULV,UOOV,YS,GO,GM,PS,KFS,KSS,/UGV,PGG,QG/1/*BKL0* $
79  SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QG,UGV,EST,,PGG/
             OPG1,OQG1,OUGV1,OES1,OEF1,PUGV1/*BKL0* $
80  OFP      OUGV1,OPG1,OQG1,OEF1,OES1,//S,N,CARDNO $
81  COND     P2,JUMPPLOT $
82  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUGV1,,GPECT,OES1/
             PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $
83  PRTMSG   PLOTX2// $
84  LABEL    P2 $
85  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/X1,X2,X3,ECPT,GPCT/LUSET/   NOSIMP/
             0/NOGENL/GENEL $
86  DSMG1    CASECC,GPTT,SIL,EDT,UGV,CSTM,MPT,ECPT,GPCT,DIT/KDGG/  S,N,
             DSCOSET $
87  EQUIV    KDGG,KDNN/MPCF2 / MGG,MNN/MPCF2 $
88  COND     LBL2D,MPCF2 $
89  MCE2     USET,GM,KDGG,MGG,,/KDNN,MNN,, $
90  LABEL    LBL2D $
91  EQUIV    KDNN,KDFF/SINGLE / MNN,MFF/SINGLE $
92  COND     LBL3D,SINGLE $
93  SCE1     USET,KDNN,MNN,,/KDFF,KDFS,KDSS,MFF,, $
94  LABEL    LBL3D $
95  EQUIV    KDFF,KDAA/OMIT / MFF,MAA/OMIT $
96  COND     LBL5D,OMIT $
97  SMP2     USET,GO,KDFF/KDAA $
98  SMP2     USET,GO,MFF/MAA $
```


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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
 99 LABEL    LBL5D $
100 PARAM    //*ADD*/DSCOSET/-1/0 $
101 EQUIV    PL,PBL/DSCOSET/PS,PBS/DSCOSET/YS,YBS/DSCOSET/UOOV,UBOOV/
             DSCOSET $
102 PARAM    //*MPY*/NDSKIP/0/0 $
103 DSMG2    MPT,KAA,KDAA,KFS,KDFS,KSS,KDSS,PL,PS,YS,UOOV/KBLL,KBFS,KBSS,
             PBL,PBS,YBS,UBOOV/S,N,NDSKIP/S,N,REPEATD/DSCOSET $
104 RBMG2    KBLL/LBLL/S,N,POWER/S,N,DET $
105 PRTPARM  //0/*DET* $
106 PRTPARM  //0/*POWER* $
107 SSG3     LBLL,KBLL,PBL,,,/UBLV,,RUBLV,/-1/V,Y,IRES/NDSKIP/  S,N,EPSI $
108 COND     LBL9D,IRES $
109 MATGPR   GPL,USET,SIL,RUBLV//*L* $
110 LABEL    LBL9D $
111 SDR1     USET,,UBLV,UBOOV,YBS,GO,GM,PBS,KBFS,KBSS,/UBGV,,QBG/NDSKIP/*
             DS1* $
112 SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QBG,UBGV,EST,,/,
             OQBG1,OUBGV1,OESB1,OEFB1,PUBGV1/*DS1* $
113 OFP      OQBG1,OUBGV1,OESB1,OEFB1,,//S,N,CARDNO $
114 DPD      DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,,,,,,,EED,EQDYN/  LUSET/
             LUSETD/NOTFL/NODLT/NOPSDL/NOFRL/  NONLFT/NOTRL/S,N,NOEED//
             NOUE $
115 COND     ERROR3,NOEED $
116 PARAM    //*MPY*/NEIGV/1/-1 $
117 READ     KBLL,MAA,,,EED,USET,CASECC/LAMA,PHIA,MI,OEIGS/*MODES*/ S,N,
             NEIGV/3 $
118 OFP      OEIGS,,,,,//S,N,CARDNO $
119 COND     ERROR4,NEIGV $
120 OFP      LAMA,,,,,//S,N,CARDNO $
121 SDR1     USET,,PHIA,,,GO,GM,,KDFS,,/PHIG,,BQG/1/*REIG* $
122 CASE     CASECC,/CASEXX/*TRANRESP*/REPEAT=3/LOOP $
123 SDR2     CASEXX,CSTM,MPT,DIT,EQEXIN,SIL,,,BGPDP,LAMA,BQG,PHIG,EST,,/,
             OBQG1,OPHIG,OBES1,OBEF1,PPHIG/*REIG* $
124 OFP      OPHIG,OBQG1,OBEF1,OBES1,,//S,N,CARDNO $
125 COND     P3,JUMPPLOT $
126 PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,,PPHIG,GPECT,
             OBES1/PLOTX3/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $
127 PRTMSG   PLOTX3// $
128 LABEL    P3 $
129 JUMP     FINIS $
130 LABEL    ERROR1 $
131 PRTPARM  //-1/*NMDS* $
```

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DISPLACEMENT APPROACH, RIGID FORMAT 13

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```
132  LABEL    ERROR2 $
133  PRTPARM  //-2/*NMDS* $
134  LABEL    ERROR3 $
135  PRTPARM  //-3/*NMDS* $
136  LABEL    ERROR4 $
137  PRTPARM  //-4/*NMDS* $
138  LABEL    ERROR5 $
139  PRTPARM  //-5/*NMDS* $
140  LABEL    ERROR6 $
141  PRTPARM  //-6/*NMDS* $
142  LABEL    FINIS $
143  PURGE    DUMMY/MINUS1 $
144  END      $
```

3.14.2 Description of DMAP Operations for Normal Modes with Differential Stiffness

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

7. GP2 generates Element Connection Table with internal indices.

10. Go to DMAP No. 18 if there are no structure plot requests.

11. PLTSET transforms user input into a form used to drive the structure plotter.

12. PRTMSG prints error messages associated with the structure plotter.

15. Go to DMAP No. 18 if no undeformed structure plots are requested.

16. PLØT generates all requested undeformed structure plots.

17. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

19. GP3 generates Static Loads Table and Grid Point Temperature Table.

20. TA1 generates element tables for use in matrix assembly and stress recovery.

21. Go to DMAP No. 130 and print Error Message No. 1 if no structural elements have been defined.

25. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

27. Go to DMAP No. 29 if no stiffness matrix is to be assembled.

28. EMA assembles stiffness matrix $[K^x_{gg}]$ and Grid Point Singularity Table.

30. Go to DMAP No. 138 and print Error Message No. 5 if no mass matrix is to be assembled.

31. EMA assembles mass matrix $[M_{gg}]$.

32. Go to DMAP No. 35 if no weight and balance information is requested.

33. GPWG generates weight and balance information.

34. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

36. Equivalence $[K^x_{gg}]$ to $[K_{gg}]$ if there are no general elements.

37. Go to DMAP No. 39 if there are no general elements.

38. SMA3 adds general elements to $[K^x_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

41. GP4 generates flags defining members of various displacement sets (USET), forms multipoint constraint equations $[R_g]\{u_g\} = 0$ and forms enforced displacement vector $\{Y_s\}$.

42. Go to DMAP No. 140 and print Error Message No. 6 if no independent degrees of freedom are defined.

45. Go to DMAP No. 47 if there are no support cards.

46. Go to DMAP No. 132 and print Error Message No. 2.

48. Go to DMAP No. 53 if general elements are present.

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50. Go to DMAP No. 53 if no potential grid point singularities exist.

51. GPSP generates a table of potential grid point singularities.

52. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

54. Equivalence $[K_{gg}]$ to $[K_{nn}]$ if no multipoint constraints exist.

55. Go to DMAP No. 58 if no multipoint constraints exist.

56. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

57. MCE2 partitions stiffness matrix

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right]$$

and performs matrix reduction

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m].$$

59. Equivalence $[K_{nn}]$ to $[K_{ff}]$ if no single-point constraints exist.

60. Go to DMAP No. 62 if no single-point constraints exist.

61. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right].$$

63. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

64. Go to DMAP No. 66 if no omitted coordinates exist.

65. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right],$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

67. RBMG2 decomposes constrained stiffness matrix $[K_{aa}] = [L_{\ell\ell}][U_{\ell\ell}]$.

68. SSG1 generates static load vectors $\{P_g\}$.

69. Equivalence $\{P_g\}$ to $\{P_\ell\}$ if no constraints are applied.

70. Go to DMAP No. 72 if no constraints are applied.

71. SSG2 applies constraints to static load vectors

$$\{P_g\} = \left\{\frac{\bar{P}_n}{P_m}\right\}, \qquad \{P_n\} = \{\bar{P}_n\} + [G_m^T]\{P_m\} ,$$

$$\{P_n\} = \left\{\frac{\bar{P}_f}{P_s}\right\}, \qquad \{P_f\} = \{\bar{P}_f\} - [K_{fs}]\{Y_s\} ,$$

$$\{P_f\} = \left\{\frac{P_a}{P_o}\right\} \text{ and } \qquad \{P_\ell\} = \{P_a\} + [G_o^T]\{P_o\} .$$

73. SSG3 solves for displacements of independent coordinates

$$\{u_\ell\} = [K_{\ell\ell}]^{-1}\{P_\ell\} ,$$

solves for displacements of omitted coordinates

$$\{u_o^o\} = [K_{oo}]^{-1}\{P_o\} ,$$

calculates residual vector (RULV) and residual vector error ratio for independent coordinates

$$\{\delta P_\ell\} = \{P_\ell\} - [K_{\ell\ell}]\{u_\ell\} ,$$

$$\varepsilon_\ell = \frac{\{u_\ell^T\}\{\delta P_\ell\}}{\{P_\ell^T\}\{u_\ell\}} ,$$

and calculates residual vector (RUØV) and residual vector error ratio for omitted coordinates

$$\{\delta P_o\} = \{P_o\} - [K_{oo}]\{u_o^o\} ,$$

$$\varepsilon_o = \frac{\{u_o^T\}\{\delta P_o\}}{\{P_o^T\}\{u_o^o\}} .$$

74. Go to DMAP No. 77 if residual vectors are not to be printed.

75. MATGPR prints the residual vector for independent coordinates (RULV).

76. MATGPR prints the residual vector for omitted coordinates (RUØV).

78. SDR1 recovers dependent displacements

$$\{u_o\} = [G_o]\{u_\ell\} + \{u_o^o\} ,$$

$$\left\{\begin{array}{c} u_a \\ \hline u_o \end{array}\right\} = \{u_f\} , \qquad \left\{\begin{array}{c} u_f \\ \hline Y_s \end{array}\right\} = \{u_n\} ,$$

$$\{u_m\} = [G_m]\{u_n\} , \qquad \left\{\begin{array}{c} u_n \\ \hline u_m \end{array}\right\} = \{u_g\}$$

and recovers single-point forces of constraint

$$\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\} + [K_{ss}]\{Y_s\} .$$

79. SDR2 calculates element forces (ØEF1) and stresses (ØES1) and prepares load vectors (ØPG1), displacement vectors (ØUGV1) and single-point forces of constraint (ØQG1) for output and translation components of the displacement vector (PUGV1) for the static solution.

80. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

81. Go to DMAP No. 84 if no static solution deformed structure plots are requested.

82. PLØT generates all requested static solution deformed structure and contour plots.

83. PRTMSG prints plotter data, engineering data, and contour data for each static solution deformed plot generated.

85. TA1 generates element tables for use in differential stiffness matrix assembly.

86. DSMG1 generates differential stiffness matrix $[K_{gg}^d]$.

87. Equivalence $[K_{gg}^d]$ to $[K_{nn}^d]$ and $[M_{gg}]$ to $[M_{nn}]$ if no multipoint constraints exist.

88. Go to DMAP No. 90 if no multipoint constraints exist.

89. MCE2 partitions differential stiffness matrix

$$[K_{gg}^d] = \left[\begin{array}{c|c} \bar{K}_{nn}^d & K_{nm}^d \\ \hline K_{mn}^d & K_{mm}^d \end{array}\right]$$

and performs matrix reduction

$$[K_{nn}^d] = [\bar{K}_{nn}^d] + [G_m^T][K_{mn}^d] + [K_{mn}^d][G_m] + [G_m^T][K_{mm}^d][G_m].$$

91. Equivalence $[K_{nn}^d]$ to $[K_{ff}^d]$ and $[M_{nn}]$ to $[M_{ff}]$ if no single-point constraints exist.

92. Go to DMAP No. 94 if no single-point constraints exist.

93. SCE1 partitions out single-point constraints

$$[K^d_{nn}] = \left[\begin{array}{c|c} K^d_{ff} & K^d_{fs} \\ \hline K^d_{sf} & K^d_{ss} \end{array}\right] \text{ and } \qquad [M_{nn}] = \left[\begin{array}{c|c} M_{ff} & M_{fs} \\ \hline M_{sf} & M_{ss} \end{array}\right] .$$

95. Equivalence $[K^d_{ff}]$ to $[K^d_{aa}]$ and $[M_{ff}]$ to $[M_{aa}]$ if no omitted coordinates exist.

96. Go to DMAP No. 99 if no omitted coordinates exist.

97. SMP2 partitions constrained differential stiffness matrix

$$[K^d_{ff}] = \left[\begin{array}{c|c} \bar{K}^d_{aa} & K^d_{ao} \\ \hline K^d_{oa} & K^d_{oo} \end{array}\right]$$

and performs matrix reduction $[K^d_{aa}] = [\bar{K}^d_{aa}] + [K^d_{ao}][G_o]$.

98. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \left[\begin{array}{c|c} \bar{M}_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right] ,$$

and performs matrix reduction

$$[M_{aa}] = [\bar{M}_{aa}] + [M^T_{oa}][G_o] + [G^T_o][M_{oa}] + [G^T_o][M_{oo}][G_o]$$

101. Equivalence $\{P_\ell\}$ to $\{P^b_\ell\}$, $\{P_s\}$ to $\{P^b_s\}$, $\{Y_s\}$ to $\{Y^b_s\}$ and $\{u^o_o\}$ to $\{u^{ob}_o\}$ if a scale factor is not specified on a DSFACT card.

103. DSMG2 adds partitions of stiffness matrix to similar partitions of differential stiffness matrix

$$[K^b_{\ell\ell}] = [K_{aa}] + \beta[K^d_{aa}] \quad ,$$

$$[K^b_{fs}] = [K_{fs}] + \beta[K^d_{fs}] \quad \text{and}$$

$$[K^b_{ss}] = [K_{ss}] + \beta[K^d_{ss}]$$

and multiplies partitions of load vectors and displacement vectors by the value of the differential stiffness scale factor (β)

$$\{P^b_\ell\} = \beta\{P_\ell\} \quad , \qquad \{P^b_s\} = \beta\{P_s\} \quad ,$$

$$\{Y^b_s\} = \beta\{Y_s\} \quad \text{and} \qquad \{u^{bo}_o\} = \beta\{u^o_o\} \quad .$$

104. RBMG2 decomposes the combined differential stiffness matrix and elastic stiffness matrix

$$[K^b_{\ell\ell}] = [L^b_{\ell\ell}][U^b_{\ell\ell}].$$

105. PRTPARM prints the scaled value of the determinant of the combined differential stiffness matrix and elastic stiffness matrix.

106. PRTPARM prints the scale factor (power of ten) of the determinant of the combined differential stiffness matrix and the elastic stiffness matrix.

107. SSG3 solves for displacements of independent coordinates for the value of differential stiffness scale factor (β)

$$\{u^b_\ell\} = [K^b_{\ell\ell}]^{-1}\{P^b_\ell\}$$

and calculates residual vector (RBULV) and residual vector error ratio for current differential stiffness load vector

$$\{\delta P^b_\ell\} = \{P^b_\ell\} - [K^b_{\ell\ell}]\{u^b_\ell\} \quad ,$$

$$\epsilon^b_\ell = \frac{\{u^b_\ell\}^T\{\delta P^b_\ell\}}{\{P^b_\ell\}^T\{u^b_\ell\}} \quad .$$

108. Go to DMAP No. 110 if the residual vector for current differential stiffness load factor is not to be printed.

109. MATGPR prints the residual vector for current differential stiffness load factor.

111. SDR1 recovers dependent displacements for the current differential stiffness scale factor

$$\{u^b_o\} = [G_o]\{u^b_\ell\} + \{u^{ob}_o\} \quad , \quad \left\{\begin{array}{c} u^b_\ell \\ \hline u^b_o \end{array}\right\} = \{u^b_f\} \quad ,$$

$$\left\{\begin{array}{c} u^b_f \\ \hline Y^b_s \end{array}\right\} = \{u^b_n\} \quad , \qquad \{u^b_m\} = [G_m]\{u^b_n\} \quad ,$$

$$\left\{\begin{array}{c} u^b_n \\ \hline u^b_m \end{array}\right\} = \{u^b_g\}$$

and recovers single-point forces of constraint for the current differential stiffness scale factor

$$\{q^b_s\} = -\{P^b_s\} + [K^b_{sf}]\{u^b_f\} + [K^b_{ff}]\{Y^b_s\} \ .$$

112. SDR2 calculates element forces (ØEFB1) and stresses (ØESB1) and prepares displacement vectors (ØUBGV1) and single-point forces of constraint (ØQBG1) for output and translation components of the displacement vector (PUBGV1) for the differential stiffness solution.

113. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

114. DPD extracts Eigenvalue Extraction Data from Dynamics data block.

115. Go to DMAP No. 134 and print Error Message No. 3 if there is no Eigenvalue Extraction Data.

117. READ extracts real eigenvalues and eigenvectors from the equation

$$[K^b_{\ell\ell} - \lambda M_{aa}]\{u_a\} = 0 \quad ,$$

calculates rigid body modes by finding a square matrix $[\phi_{ro}]$ such that

$$[m_o] = [\phi^T_{ro}][m_r][\phi_{ro}]$$

is diagonal and normalized, computes rigid body eigenvectors

$$[\phi_{ao}] = \left[\begin{array}{c} D\phi_{ro} \\ \hline \phi_{ro} \end{array}\right] \quad ,$$

calculates modal mass matrix

$$[m] = [\phi^T_a][M_{aa}][\phi_a]$$

and normalizes eigenvectors according to one of the following user requests:

1) Unit value of a selected component
2) Unit value of the largest component
3) Unit value of the generalized mass.

118. ØFP formats the summary of eigenvalue extraction information (ØEIGS) prepared by READ and places it on the system output file for printing.

119. Go to DMAP No. 136 and print Error Message No. 4 if no eigenvalues were found.

120. ØFP formats the eigenvalues (LAMA) prepared by READ and places them on the system output file for printing.

121. SDR1 recovers dependent components of the eigenvectors

$$\{\phi_o\} = [G_o]\{\phi_a\} \quad , \qquad \left\{\begin{array}{c} \phi_a \\ \hline \phi_o \end{array}\right\} = \{\phi_f\} \quad ,$$

$$\left\{\begin{array}{c} \phi_f \\ \hline \phi_s \end{array}\right\} = \{\phi_n\} \quad , \qquad \{\phi_m\} = [G_m]\{\phi_n\} \quad ,$$

$$\left\{\begin{array}{c} \phi_n \\ \hline \phi_m \end{array}\right\} = \{\phi_g\}$$

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and recovers single-point forces of constraint $\{q_s\} = [K_{fs}]^T\{\phi_f\}$.

122. CASE copies the record corresponding to the third subcase from CASECC into CASEXX.

123. SDR2 calculates element forces (ØBEF1) and stresses (ØBES1) and prepares eigenvectors (ØPHIG) and single-point forces of constraint (ØBQG1) for output and translation components of the eigenvectors (PPHIG) for the normal mode solution.

124. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

125. Go to DMAP No. 128 if no real eigenvalue solution deformed structure plots are requested.

126. PLØT generates all requested real eigenvalue solution deformed structure and contour plots.

127. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.

129. Go to DMAP No. 142 and make normal exit.

131. Print Error Message No. 1 and terminate execution.

133. Print Error Message No. 2 and terminate execution.

135. Print Error Message No. 3 and terminate execution.

137. Print Error Message No. 4 and terminate execution.

139. Print Error Message No. 5 and terminate execution.

141. Print Error Message No. 6 and terminate execution.

3.14.3 Output for Normal Modes with Differential Stiffness

The Eigenvalue Summary Table and the Eigenvalue Analysis Summary, as described under Normal Mode Analysis (see Section 3.4.3), are automatically printed.

The value of the determinant of the sum of the elastic stiffness and the differential stiffness is also automatically printed.

The following output may be requested:

1. Nonzero components of the applied static load for the linear solution at selected grid points.
2. Displacement and nonzero components of the single-point forces of constraint, with and without differential stiffness, at selected grid points.
3. Forces and stresses in selected elements, with and without differential stiffness.
4. Deformed and undeformed plots with and without differential stiffness.
5. Contour plots of stresses and displacements with and without differential stiffness.

The following output may be requested for the Normal Mode Analysis subcase:

1. Eigenvectors along with the associated eigenvalue for each mode.
2. Nonzero components of the single-point forces of constraint for selected modes at selected grid points.
3. Forces and stresses in selected elements for selected modes.
4. Undeformed plot of the structural model and mode shapes for selected modes.
5. Contour plots of stresses and displacements for selected modes.

3.14.4 Case Control Deck for Normal Modes with Differential Stiffness

The following items relate to subcase definition and data selection for Normal Modes with Differential Stiffness:

1. The Case Control Deck must contain three subcases. Output selections may be made above the subcase level and within the individual subcases.
2. The linear solution is output from the first subcase. The static differential stiffness solution is output from the second subcase. The eigenvector solution is output from the third subcase.
3. An SPC set must be selected above the subcase level unless all constraints are specified on GRID cards.

4. A static loading condition must be defined in the first subcase with a LØAD, TEMPERATURE(LØAD), or DEFØRM selection, unless all loading is specified by grid point displacements on SPC cards.
5. DSCØEFFICIENT must appear in the second subcase, either to select a DSFACT set from the Bulk Data Deck, or to explicitly select the DEFAULT value of unity.
6. METHØD must appear in the third subcase to select an EIGR bulk data card.

3.14.5 Parameters for Normal Modes with Differential Stiffness

The following parameters are used in Normal Modes with Differential Stiffness:

1. GRDPNT - optional. A positive integer value of this parameter will cause the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
2. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in EMA. Not recommended for use in hydroelastic problems.
3. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters willl cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
5. AUTØSPC - reserved for future optional use. The default value is -1.

3.14.6 Optional Diagnostic Output for FEER

Special detailed information obtained by requesting DIAG 16 in the Executive Control Deck is the same as that described under Normal Mode Analysis (see Section 3.4.6).

3.14.7 The APPEND Feature

The APPEND feature can be used for real eigenvalue extraction in Normal Modes with Differential Stiffness. See Section 3.4.7 for details.

3.14.8 Rigid Format Error Messages from Normal Modes with Differential Stiffness

The following fatal errors are detected by the DMAP statements in the Normal Modes with Differential Stiffness rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

NØRMAL MØDES WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 1 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

NØRMAL MØDES WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 2 - FREE BØDY SUPPØRTS NØT ALLØWED.

Free bodies are not allowed in Normal Modes with Differential Stiffness. The SUPØRT cards must be removed from the Bulk Data Deck and other constraints applied if required for stability.

NØRMAL MØDES WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 3 - EIGENVALUE EXTRACTIØN DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGR card in the Bulk Data Deck and METHØD in the Case Control Deck must select an EIGR set.

NØRMAL MØDES WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 4 - NØ EIGENVALUE FØUND.

No eigenvalues were found in the frequency range specified by the user.

NØRMAL MØDES WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 5 - MASS MATRIX REQUIRED FØR REAL EIGENVALUE ANALYSIS.

The mass matrix is null because either no structural elements were defined with Connection cards, nonstructural mass was not defined on a Property card or the density was not defined on a Material card.

NØRMAL MØDES WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 6 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, SUPØRT, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

3.15 STATIC ANALYSIS USING CYCLIC SYMMETRY

3.15.1 DMAP Sequence for Static Analysis Using Cyclic Symmetry

```
RIGID FORMAT DMAP LISTING
RELEASE APR. 1984

DISPLACEMENT APPROACH, RIGID FORMAT 14

    LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING


OPTIONS IN EFFECT   GO     ERR=2   LIST    NODECK  NOREF   NOOSCAR
-----------------

   1  BEGIN    DISP 14 - STATIC ANALYSIS WITH CYCLIC SYMMETRY - APR. 1984 $
   2  PRECHK   ALL $
   3  FILE     KKK=SAVE/PK=SAVE $
   4  FILE     UXV=APPEND $
   5  PARAM    //*MPY*/CARDNO/0/0 $
   6  PARAM    //*NOP*/V,Y,CYCIO=1 $
   7  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  NOGPDT/
               MINUS1=-1 $
   8  PLTTRAN  BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $
   9  GP2      GEOM2,EQEXIN/ECT $
  10  PARAML   PCDB//*PRES*////JUMPPLOT $
  11  PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $
  12  COND     P1,JUMPPLOT $
  13  PLTSET   PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/   S,N,
               JUMPPLOT $
  14  PRTMSG   PLTSETX// $
  15  PARAM    //*MPY*/PLTFLG/1/1 $
  16  PARAM    //*MPY*/PFILE/0/0 $
  17  COND     P1,JUMPPLOT $
  18  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
               NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $
  19  PRTMSG   PLOTX1// $
  20  LABEL    P1 $
  21  GP3      GEOM3,EQEXIN,GEOM2/SLT,GPTT/S,N,NOGRAV $
  22  PARAM    //*AND*/NONGG/NOGRAV/V,Y,GRDPNT=-1 $
  23  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/LUSET/S,N,NOSIMP/1/
               S,N,NOGENL/S,N,GENEL $
  24  PARAM    //*AND*/NOELMT/NOGENL/NOSIMP $
  25  COND     ERROR4,NOELMT $
  26  PURGE    GPST/NOSIMP/OGPST/GENEL $
  27  COND     LBL1,NOSIMP $
  28  PARAM    //*ADD*/NOKGGX/1/0 $
  29  EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,/S,N,NOKGGX/ S,
               N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/C,Y,CPQUAD1/C,Y,
               CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/  C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,
               CPTRPLT/C,Y,CPTRBSC $
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OF POOR QUALITY

RIGID FORMAT DMAP LISTING
RELEASE APR. 1984

DISPLACEMENT APPROACH, RIGID FORMAT 14

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```
 30  PURGE   KGGX,GPST/NOKGGX/MGG/NOMGG $
 31  COND    JMPKGG,NOKGGX $
 32  EMA     GPECT,KDICT,KELM/KGGX,GPST $
 33  LABEL   JMPKGG $
 34  COND    JMPMGG,NOMGG $
 35  EMA     GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $
 36  LABEL   JMPMGG $
 37  COND    LBL1,GRDPNT $
 38  COND    ERROR2,NOMGG $
 39  GPWG    BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT/C,Y,WTMASS $
 40  OFP     OGPWG,,,,,//S,N,CARDNO $
 41  LABEL   LBL1 $
 42  EQUIV   KGGX,KGG/NOGENL $
 43  COND    LBL11A,NOGENL $
 44  SMA3    GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $
 45  LABEL   LBL11A $
 46  PARAM   //*MPY*/NSKIP/0/0 $
 47  GP4     CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,YS,USET,ASET/
             LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/S,N,
             NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/ S,Y,
             AUTOSPC $
 48  COND    ERROR3,NOL $
 49  PARAM   //*NOT*/REACDATA/REACT $
 50  COND    ERROR6,REACDATA $
 51  PURGE   GM/MPCF1/GO,KOO,LOO PO,UOOV,RUOV/OMIT/PS,KFS,KSS,QG/SINGLE $
 52  GPCYC   GEOM4,EQEXIN,USET/CYCD/V,Y,CTYPE/S,N,NOGO $
 53  COND    ERROR7,NOGO $
 54  COND    LBL4,GENEL $
 55  PARAM   //*EQ*/GPSPFLG/AUTOSPC/0 $
 56  COND    LBL4,GPSPFLG $
 57  GPSP    GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
 58  OFP     OGPST,,,,,//S,N,CARDNO $
 59  LABEL   LBL4 $
 60  EQUIV   KGG,KNN/MPCF1 $
 61  COND    LBL2,MPCF1 $
 62  MCE1    USET,RG/GM $
 63  MCE2    USET,GM,KGG,,,/KNN,,, $
 64  LABEL   LBL2 $
 65  EQUIV   KNN,KFF/SINGLE $
```

RIGID FORMAT DMAP LISTING
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DISPLACEMENT APPROACH, RIGID FORMAT 14

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
 66  COND     LBL3,SINGLE $
 67  SCE1     USET,KNN,,,/KFF,KFS,KSS,,, $
 68  LABEL    LBL3 $
 69  EQUIV    KFF,KAA/OMIT $
 70  COND     LBL5,OMIT $
 71  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
 72  LABEL    LBL5 $
 73  SSG1     SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,CASECC,DIT,/PG,,,,/
              LUSET/NSKIP $
 74  EQUIV    PG,PL/NOSET $
 75  COND     LBL9,NOSET $
 76  SSG2     USET,GM,YS,KFS,GO,,PG/,PO,PS,PL $
 77  COND     LBL9,OMIT $
 78  SSG3     LOO,KOO,PO,,,/UOOV,,RUOV,/-1/V,Y,IRES=-1 $
 79  COND     LBL9,IRES $
 80  MATGPR   GPL,USET,SIL,RUOV//*O* $
 81  LABEL    LBL9 $
 82  EQUIV    PL,PX/CYCIO $
 83  COND     LBL10,CYCIO $
 84  CYCT1    PL/PX,GCYCF/V,Y,CTYPE/*FORE*/V,Y,NSEGS=-1/S,Y,KMAX=-1/V,Y,
              NLOAD=1/S,N,NOGO $
 85  LABEL    LBL10 $
 86  COND     ERROR7,NOGO $
 87  PARAM    //*ADD*/KINDEX/0/0 $               Top of Cyclic Index Value Loop
 88  LABEL    LBL11 $
 89  CYCT2    CYCD,KAA,,PX,,/KKK,,PK,,/*FORE*/V,Y,NSEGS/KINDEX/V,Y, CYCSEQ=
              -1/V,Y,NLOAD/S,N,NOGO $
 90  COND     ERROR7,NOGO $
 91  RBMG2    KKK/LKK $
 92  SSG3     LKK,KKK,PK,,,/UKV,,RUKV,/-1/V,Y,IRES $
 93  CYCT2    CYCD,,,UKV,RUKV,/,,UXV,RUXV,/*BACK*/V,Y,NSEGS/KINDEX/ V,Y,
              CYCSEQ/V,Y,NLOAD/S,N,NOGO $
 94  COND     ERROR7,NOGO $
 95  COND     LBL14,IRES $
 96  MATGPR   GPL,USET,SIL,RUXV//*A* $
 97  LABEL    LBL14 $
 98  PARAM    //*ADD*/KINDEX/KINDEX/1 $
 99  PARAM    //*SUB*/DONE/V,Y,KMAX/KINDEX $
100  COND     LBL15,DONE $
```

RIGID FORMAT DMAP LISTING
RELEASE APR. 1984

DISPLACEMENT APPROACH, RIGID FORMAT 14

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
101  REPT     LBL11,360 $                    Bottom of Cyclic Index Value Loop
102  JUMP     ERROR1 $
103  LABEL    LBL15 $
104  EQUIV    UXV,ULV/CYCIO $
105  COND     LBL16,CYCIO $
106  CYCT1    UXV/ULV,GCYCB/V,Y,CTYPE/*BACK*/V,Y,NSEGS/V,Y,KMAX/V,Y,NLOAD/
              S,N,NOGO $
107  COND     ERROR7,NOGO $
108  LABEL    LBL16 $
109  SDR1     USET,PG,ULV,UOOV,YS,GO,GM,PS,KFS,KSS,/UGV,PGG,QG/NSKIP/*
              STATICS* $
110  COND     NOMPCF,GRDEQ $
111  EQMCK    CASECC,EQEXIN,GPL,BGPDT,SIL,USET,KGG,GM,UGV,PGG,QG,CSTM/  OQM1/
              V,Y,OPT=0/V,Y,GRDEQ/NSKIP $
112  OFP      OQM1,,,,,//S,N,CARDNO $
113  LABEL    NOMPCF $
114  SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QG,UGV,EST,,PGG/
              OPG1,OQG1,OUGV1,OES1,OEF1,PUGV1/*STATICS* $
115  OFP      OUGV1,OPG1,OQG1,OEF1,OES1,//S,N,CARDNO $
116  COND     P2,JUMPPLOT $
117  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUGV1,,GPECT,OES1/
              PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $
118  PRTMSG   PLOTX2// $
119  LABEL    P2 $
120  JUMP     FINIS $
121  LABEL    ERROR1 $
122  PRTPARM  //-1/*CYCSTATICS* $
123  LABEL    ERROR2 $
124  PRTPARM  //-2/*CYCSTATICS* $
125  LABEL    ERROR3 $
126  PRTPARM  //-3/*CYCSTATICS* $
127  LABEL    ERROR4 $
128  PRTPARM  //-4/*CYCSTATICS* $
129  LABEL    ERROR6 $
130  PRTPARM  //-6/*CYCSTATICS* $
131  LABEL    ERROR7 $
132  PRTPARM  //-7/*CYCSTATICS* $
133  LABEL    FINIS $
134  PURGE    DUMMY/MINUS1 $
135  END      $
```

3.15.2 Description of DMAP Operations for Static Analysis Using Cyclic Symmetry

7. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

8. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

9. GP2 generates Element Connection Table with internal indices.

12. Go to DMAP No. 20 if there are no structure plot requests.

13. PLTSET transforms user input into a form used to drive the structure plotter.

14. PRTMSG prints error messages associated with the structure plotter.

17. Go to DMAP No. 20 if no undeformed structure plots are requested.

18. PLØT generates all requested undeformed structure plots.

19. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

21. GP3 generates Static Loads Table and Grid Point Temperature Table.

23. TA1 generates element tables for use in matrix assembly and stress recovery.

25. Go to DMAP No. 127 and print Error Message No. 4 if no elements have been defined.

27. Go to DMAP No. 41 if there are no structural elements.

29. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

31. Go to DMAP No. 33 if no stiffness matrix is to be assembled.

32. EMA assembles stiffness matrix $[K^x_{gg}]$ and Grid Point Singularity Table.

34. Go to DMAP No. 36 if no mass matrix is to be assembled.

35. EMA assembles mass matrix $[M_{gg}]$.

37. Go to DMAP No. 41 if no weight and balance information is requested.

38. Go to DMAP No. 123 and print Error Message No. 2 if no mass matrix exists.

39. GPWG generates weight and balance information.

40. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

42. Equivalence $[K^x_{gg}]$ to $[K_{gg}]$ if there are no general elements.

43. Go to DMAP No. 45 if there are no general elements.

44. SMA3 adds general elements to $[K^x_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

47. GP4 generates flags defining members of various displacement sets (USET), forms multipoint constraint equations $[R_g]\{u_g\} = 0$ and forms enforced displacement vector $\{Y_s\}$.

48. Go to DMAP No. 125 and print Error Message No. 3 if no independent degrees of freedom are defined.

50. Go to DMAP No. 129 and print Error Message No. 6 if free-body supports are present.

52. GPCYC prepares segment boundary table (CYCD).

53. Go to DMAP No. 131 and print Error Message No. 7 if CYJØIN data is inconsistent.

54. Go to DMAP No. 59 if general elements are present.

56. Go to DMAP No. 59 if no potential grid point singularities exist.

57. GPSP generates a table of potential grid point singularities.

58. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

60. Equivalence $[K_{gg}]$ to $[K_{nn}]$ if no multipoint constraints exist.

61. Go to DMAP No. 64 if no multipoint constraints exist.

62. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

63. MCE2 partitions stiffness matrix

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right]$$

and performs matrix reduction

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m].$$

65. Equivalence $[K_{nn}]$ to $[K_{ff}]$ if no single-point constraints exist.

66. Go to DMAP No. 68 if no single-point constraints exist.

67. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right].$$

69. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

70. Go to DMAP No. 72 if no omitted coordinates exist.

71. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right],$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

73. SSG1 generates static load vectors $\{P_g\}$.

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74. Equivalence $\{P_g\}$ to $\{P_\ell\}$ if no constraints are applied.

75. Go to DMAP No. 81 if no constraints are applied.

76. SSG2 applies constraints to static load vectors

$$\{P_g\} = \begin{Bmatrix} \bar{P}_n \\ \hline P_m \end{Bmatrix} , \qquad \{P_n\} = \{\bar{P}_n\} + [G_m^T]\{P_m\} ,$$

$$\{P_n\} = \begin{Bmatrix} \bar{P}_f \\ \hline P_s \end{Bmatrix} , \qquad \{P_f\} = \{\bar{P}_f\} - [K_{fs}]\{Y_s\} ,$$

$$\{P_f\} = \begin{Bmatrix} \bar{P}_a \\ \hline P_o \end{Bmatrix} , \qquad \{P_a\} = \{\bar{P}_a\} + [G_o^T]\{P_o\} ,$$

$$\{P_a\} = \begin{Bmatrix} P_\ell \\ \hline P_r \end{Bmatrix}$$

and calculates determinate forces of reaction $\{q_r\} = -\{P_r\} - [D^T]\{P_\ell\}$.

77. Go to DMAP No. 81 if no omitted coordinates exist.

78. SSG3 solves for displacements of omitted coordinates (these are not transformed)

$$\{u_o^o\} = [K_{oo}]^{-1}\{P_o\}$$

and calculates residual vector (RUØV) and residual vector error ratio for omitted coordinates

$$\{\delta P_o\} = \{P_o\} - [K_{oo}]\{u_o^o\} ,$$

$$\varepsilon_o = \frac{\{u_o^T\}\{\delta P_o\}}{\{P_o^T\}\{u_o^o\}} .$$

79. Go to DMAP No. 81 if residual vectors are not to be printed.

80. MATGPR prints the residual vector for omitted coordinates (RUØV).

82. Equivalence $\{P_\ell\}$ to $\{P_x\}$ if symmetric components of loads have been input.

83. Go to DMAP No. 85 if symmetric conponents of loads have been input.

84. CYCT1 transforms loads on analysis points to symmetric components by the equation

$$\{P_x\} = [G]\{P_\ell\} .$$

86. Go to DMAP No. 131 and print Error Message No. 7 if a CYCT1 error was found.

88. Beginning of loop for cyclic index (KINDEX) values.

89. CYCT2 transforms matrices and loads from symmetric components to solution set by the equations

$$[K_{kk}] = [G_1^T][K_{aa}][G_1] + [G_2^T][K_{aa}[G_2] ,$$

where $G_1 = G_c$ (cosine) and $G_2 = G_s$ (sine) for rotational symmetry,

and $G_1 = G_S$ (Symmetric) and $G_2 = G_A$ (Antisymmetric) for dihedral symmetry,

$$\{P_k\} = [G_c^T]\{P_c\} + [G_s^T]\{P_s\} \text{ for rotational symmetry,}$$

$$\{P_k^1\} = [G_S^T]\{P_{cS}\} + [G_A^T]\{P_{sA}\} ,$$

and $\{P_k^2\} = [G_A^T]\{P_{cA}\} + [G_S^T]\{P_{sS}\}$ for dihedral symmetry.

90. Go to DMAP No. 131 and print Error Message No. 7 if a CYCT2 error was found.

91. RBMG2 decomposes constrained stiffness matrix for solution set

$$[K_{kk}] = [L_{kk}][U_{kk}]$$

92. SSG3 solves for displacements of solution set coordinates

$$\{u_k\} = [K_{kk}]^{-1}\{P_k\}$$

and calculates residual vector (RUKV) and residual vector error ratio for solution set coordinates

$$\{\delta P_k\} = \{P_k\} - [K_{kk}]\{u_k\} ,$$

$$\varepsilon_k = \frac{\{u_k^T\}\{\delta P_k\}}{\{P_k^T\}\{u_k\}} .$$

93. CYCT2 finds symmetric components of displacement from solution set data and appends to output for each KINDEX.

94. Go to DMAP No. 131 and print Error Message No. 7 if a CYCT2 error was found.

95. Go to DMAP No. 97 if residual vectors are not to be printed.

96. MATGPR prints the residual vector for solution set coordinates (RUXV).

100. Go to DMAP No. 103 if all cyclic index (KINDEX) values are complete.

101. Go to DMAP No. 88 if additional cyclic index values are needed.

102. Go to DMAP No. 121 and print Error Message No. 1 if number of loops exceeds 360.

104. Equivalence $\{u_x\}$ to $\{u_\ell\}$ if output of symmetric components was requested.

105. Go to DMAP No. 108 if output of symmetric components was requested.

106. CYCT1 transforms displacements from symmetric components to physical components.

107. Go to DMAP No. 131 and print Error Message No. 7 if a CYCT1 error was found.

109. SDR1 recovers dependent displacements

$$\{u_o\} = [G_o]\{u_a\} + \{u_o^o\} \;,$$

$$\left\{\frac{u_a}{u_o}\right\} = \{u_f\} \;, \qquad \left\{\frac{u_f}{Y_s}\right\} = \{u_n\} \;,$$

$$\{u_m\} = [G_m]\{u_n\} \;, \qquad \left\{\frac{u_n}{u_m}\right\} = \{u_g\}$$

and recovers single-point forces of constraint

$$\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\} + [K_{ss}]\{Y_s\} \;.$$

110. Go to DMAP No. 113 if no multipoint constraint force balance is requested.

111. EQMCK calculates the force and moment equilibrium check and prepares the multipoint constraint force balance (ØQM1) for output.

112. ØFP formats the table prepared by EQMCK and places it on the system output file for printing.

114. SDR2 calculates element forces (ØEF1) and stresses (ØES1) and prepares load vectors (ØPG1), displacement vectors (ØUGV1) and single-point forces of constraint (ØQG1) for output and translation components of the displacement vector (PUGV1).

115. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

116. Go to DMAP No. 119 if no deformed structure plots are requested.

117. PLØT generates all requested deformed structure and contour plots.

118. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.

120. Go to DMAP No. 133 and make normal exit.

122. Print Error Message No. 1 and terminate execution.

124. Print Error Message No. 2 and terminate execution.

126. Print Error Message No. 3 and terminate execution.

128. Print Error Message No. 4 and terminate execution.

130. Print Error Message No. 6 and terminate execution.

132. Print Error Message No. 7 and terminate execution.

3.15.3 Output for Static Analysis Using Cyclic Symmetry

The following printed output, for each loading condition and each symmetric segment or index, may be requested for Static Analysis Using Cyclic Symmetry:

1. Displacements and components of static loads and single-point forces of constraint at selected grid points or scalar points.
2. Forces and streses in selected elements.

The following plotter output may be requested:

1. Undeformed and deformed plots of the structural model (1 segment).
2. Contour plots of stresses and displacements (1 segment).
3. X-Y plot of any component of displacement, static load, or single-point force of constraint for a grid point or scalar point.
4. X-Y plot of any stress or force component for an element.

3.15.4 Case Control Deck for Static Analysis Using Cyclic Symmetry

The following items relate to subcase definition and data selection for Static Analysis Using Cyclic Symmetry:

1. A separate group of subcases must be defined for each symmetric segment. For dihedral symmetry, a separate group of subcases must be defined for each half. There may be up to 360 subcases corresponding to 1° segments.
2. The different loading conditions are defined within each group of subcases. The loads on each symmetric segment and the selected output requests may be independent. The number of loading cases is specified on the PARAM card NLØAD.
3. The SPC and MPC request must appear above the subcase level and may not be changed.
4. An alternate loading method is to define a separate group of subcases for each harmonic index, k. The parameter CYCIØ is included and the load components for each index are defined directly within each group for the various loading conditions.

3.15.5 Parameters for Static Analysis Using Cyclic Symmetry

The following parameters are used in Static Analysis Using Cyclic Symmetry:

1. GRDPNT - optional. A positive integer value of this parameter will cause the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed.

2. WTMASS - optional. The terms of the mass matrix are multiplied by the real value of this parameter when they are generated in EMA.
3. IRES - optional. A positive integer value of this parameter will cause the printing of the residual vectors following the execution of SSG3.
4. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters will cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
5. CTYPE - required. The BCD value of this parameter defines the type of cyclic symmetry as follows:
   (1) RØT - rotational symmetry
   (2) DRL - dihedral symmetry, using right and left halves
   (3) DSA - dihedral symmetry, using symmetric and antisymmetric components
6. NSEGS - required. The integer value of this parameter is the number of identical segments in the structural model.
7. NLØAD - optional. The integer value of this parameter is the number of static loading conditions. The default value is 1.
8. CYCIØ - optional. The integer value of this parameter specifies the form of the input and output data. A value of +1 is used to specify physical segment representation, and a value of -1 for cyclic transform representation. The default value is +1.
9. CYCSEQ - optional. The integer value of this parameter specifies the procedure for sequencing the equations in the solution set. A value of +1 specifies that all cosine terms should be sequenced before all sine terms, and a value of -1 for alternating the cosine and sine terms. The default value is -1.
10. KMAX - optional. The integer value of this parameter specifies the maximum value of the harmonic index. The default value is ALL which is NSEGS/2 for NSEGS even and (NSEGS-1)/2 for NSEGS odd.
11. ØPT - optional. A positive integer value of this parameter causes both equilibrium and multipoint constraint forces to be calculated for the Case Control output request, MPCFØRCE. A negative integer value of this parameter causes only the equilibrium force balance to be calculated for the output request. The default value is 0 which causes only the multipoint constraint forces to be calculated for the output request.

12. GRDEQ - optional. A positive integer value of this parameter selects the grid point about which equilibrium will be checked for the Case Control output request, MPCFØRCE. If the integer value is zero, the basic origin is used. Default is -1.

13. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.

14. AUTØSPC - reserved for future optional use. The default value is -1.

3.15.6 Rigid Format Error Messages from Static Analysis Using Cyclic Symmetry

The following fatal errors are detected by the DMAP statements in the Static Analysis Using Cyclic Symmetry rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

STATICS WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 1 - ATTEMPT TØ EXECUTE MØRE THAN 360 LØØPS.

An attempt has been made to use more than 360 cyclic index (KINDEX) values. This number may be increased by ALTERing the REPT instruction in the DMAP.

STATICS WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 2 - MASS MATRIX REQUIRED FØR WEIGHT AND BALANCE CALCULATIØNS.

The mass matrix is null because either no elements were defined with Connection cards, nonstructural mass was not defined on a Property card or the density was not defined on a Material card.

STATICS WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 3 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, SUPØRT, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

STATICS WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 4 - NØ ELEMENTS HAVE BEEN DEFINED.

No elements have been defined with either Connection cards or GENEL cards.

STATICS WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 6 - FREE BØDY SUPPØRTS NØT ALLØWED.

Free bodies are not allowed in Static Analysis Using Cyclic Symmetry. The SUPØRT cards must be removed from the Bulk Data Deck and other constraints applied if required for stability.

STATICS WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 7 - CYCLIC TRANSFØRMATIØN DATA ERRØR.

See Section 1.12 proper modeling techniques and corresponding PARAM card requirements.

3.16 NORMAL MODES ANALYSIS USING CYCLIC SYMMETRY

3.16.1 DMAP Sequence for Normal Modes Analysis Using Cyclic Symmetry

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RIGID FORMAT DMAP LISTING
RELEASE APR. 1984

DISPLACEMENT APPROACH, RIGID FORMAT 15

    LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

OPTIONS IN EFFECT   GO    ERR=2   LIST    NODECK  NOREF   NOOSCAR

   1 BEGIN     DISP 15 NORMAL MODES ANALYSIS WITH CYCLIC SYMMETRY-APR. 1984 $
   2 PRECHK    ALL $
   3 PARAM     //*MPY*/CARDNO/0/0 $
   4 GP1       GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  NOGPDT/
               MINUS1=-1 $
   5 PLTTRAN   BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $
   6 GP2       GEOM2,EQEXIN/ECT $
   7 PARAML    PCDB//*PRES*////JUMPPLOT $
   8 PURGE     PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $
   9 COND      P1,JUMPPLOT $
  10 PLTSET    PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/   S,N,
               JUMPPLOT $
  11 PRTMSG    PLTSETX// $
  12 PARAM     //*MPY*/PLTFLG/1/1 $
  13 PARAM     //*MPY*/PFILE/0/0 $
  14 COND      P1,JUMPPLOT $
  15 PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
               NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $
  16 PRTMSG    PLOTX1//$
  17 LABEL     P1 $
  18 GP3       GEOM3,EQEXIN,GEOM2/,GPTT/NOGRAV $
  19 TA1       ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/LUSET/S,N,NOSIMP/1/
               S,N,NOGENL/S,N,GENEL $
  20 COND      ERROR6,NOSIMP $
  21 PURGE     OGPST/GENEL $
  22 PARAM     //*ADD*/NOKGGX/1/0 $
  23 PARAM     //*ADD*/NOMGG/1/0 $
  24 EMG       EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,/S,N,NOKGGX/ S,
               N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/  C,Y,CPQUAD1/C,Y,
               CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/C,Y,CPTUBE/ C,Y,CPQDPLT/C,Y,
               CPTRPLT/C,Y,CPTRBSC $
  25 PURGE     KGGX,GPST/NOKGGX $
  26 COND      JMPKGG,NOKGGX $
  27 EMA       GPECT,KDICT,KELM/KGGX,GPST $
  28 LABEL     JMPKGG $
  29 COND      ERROR1,NOMGG $
```

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```
30 EMA     GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $
31 COND    LGPWG,GRDPNT $
32 GPWG    BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $
33 OFP     OGPWG,,,,,//S,N,CARDNO $
34 LABEL   LGPWG $
35 EQUIV   KGGX,KGG/NOGENL $
36 COND    LBL11,NOGENL $
37 SMA3    GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $
38 LABEL   LBL11 $
39 PARAM   //*MPY*/NSKIP/0/0 $
40 GP4     CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,USET,ASET/ LUSET/
           S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/S,N,NSKIP/S,
           N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/ S,Y,AUTOSPC $
41 COND    ERROR3,NOL $
42 PARAM   //*NOT*/REACDATA/REACT $
43 COND    ERROR4,REACDATA $
44 PURGE   GM/MPCF1/GO/OMIT/KFS,QG/SINGLE $
45 GPCYC   GEOM4,EQEXIN,USET/CYCD/V,Y,CTYPE/S,N,NOGO $
46 COND    ERROR5,NOGO $
47 COND    LBL4,GENEL $
48 PARAM   //*EQ*/GPSPFLG/AUTOSPC/0 $
49 COND    LBL4,GPSPFLG $
50 GPSP    GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
51 OFP     OGPST,,,,,//S,N,CARDNO $
52 LABEL   LBL4 $
53 EQUIV   KGG,KNN/MPCF1/MGG,MNN/MPCF1 $
54 COND    LBL2,MPCF1 $
55 MCE1    USET,RG/GM $
56 MCE2    USET,GM,KGG,MGG,,/KNN,MNN,, $
57 LABEL   LBL2 $
58 EQUIV   KNN,KFF/SINGLE/MNN,MFF/SINGLE $
59 COND    LBL3,SINGLE $
60 SCE1    USET,KNN,MNN,,/KFF,KFS,,MFF,, $
61 LABEL   LBL3 $
62 EQUIV   KFF,KAA/OMIT $
63 EQUIV   MFF,MAA/OMIT $
64 COND    LBL5,OMIT $
65 SMP1    USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
```

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```
66  SMP2     USET,GO,MFF/MAA $
67  LABEL    LBL5 $
68  DPD      DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,,,,,,,EED,EQDYN/  LUSET/
             LUSETD/NOTFL/NODLT/NOPSDL/NOFRL/  NONLFT/NOTRL/S,N,NOEED//
             NOUE $
69  COND     ERROR2,NOEED $
70  CYCT2    CYCD,KAA,MAA,,,/KKK,MKK,,,/*FORE*/V,Y,NSEGS=-1/V,Y,KINDEX=-1/
             V,Y,CYCSEQ=-1/1/S,N,NOGO $
71  COND     ERROR5,NOGO $
72  READ     KKK,MKK,,EED,,CASECC/LAMK,PHIK,MI,OEIGS/*MODES*/S,N,NEIGV $
73  OFP      OEIGS,,,,,//S,N,CARDNO $
74  COND     FINIS,NEIGV $
75  OFP      LAMK,,,,,//S,N,CARDNO $
76  CYCT2    CYCD,,,,PHIK,LAMK/,,,PHIA,LAMA/*BACK*/V,Y,NSEGS/V,Y,KINDEX/
             V,Y,CYCSEQ/1/S,N,NOGO $
77  COND     ERROR5,NOGO $
78  SDR1     USET,,PHIA,,,GO,GM,,KFS,,/PHIG,,QG/1/*REIG* $
79  COND     NOMPCF,GRDEQ $
80  EQMCK    CASECC,EQEXIN,GPL,BGPDT,SIL,USET,KGG,GM,PHIG,LAMA,QG,CSTM/OQM1/
             V,Y,OPT=0/V,Y,GRDEQ/-1 $
81  OFP      OQM1,,,,,//S,N,CARDNO $
82  LABEL    NOMPCF $
83  SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,,,BGPDT,LAMA,QG,PHIG,EST,,/,
             OQG1,OPHIG,OES1,OEF1,PPHIG/*REIG* $
84  OFP      OPHIG,OQG1,OEF1,OES1,,//S,N,CARDNO $
85  COND     P2,JUMPPLOT $
86  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,,PPHIG,GPECT,OES1/
             PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $
87  PRTMSG   PLOTX2// $
88  LABEL    P2 $
89  JUMP     FINIS $
90  LABEL    ERROR1 $
91  PRTPARM  //-1/*CYCMODES* $
92  LABEL    ERROR2 $
93  PRTPARM  //-2/*CYCMODES* $
94  LABEL    ERROR3 $
95  PRTPARM  //-3/*CYCMODES* $
96  LABEL    ERROR4 $
97  PRTPARM  //-4/*CYCMODES* $
98  LABEL    ERROR5 $
99  PRTPARM  //-5/*CYCMODES* $
```

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```
100  LABEL    ERROR6 $
101  PRTPARM  //-6/*CYCMODES* $
102  LABEL    FINIS $
103  PURGE    DUMMY/MINUS1 $
104  END      $
```

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3.16.2 Description of DMAP Operations for Normal Modes Analysis Using Cyclic Symmetry

4. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

5. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.

6. GP2 generates Element Connection Table with internal indices.

9. Go to DMAP No. 17 if there are no structure plot requests.

10. PLTSET transforms user input into a form used to drive the structure plotter.

11. PRTMSG prints error messages associated with the structure plotter.

14. Go to DMAP No. 17 if no undeformed structure plots are requested.

15. PLØT generates all requested undeformed structure plots.

16. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

18. GP3 generates Static Loads Table and Grid Point Temperature Table.

19. TA1 generates element tables for use in matrix assembly and stress recovery.

20. Go to DMAP No. 100 and print Error Message No. 6 if no structural elements have been defined.

24. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

26. Go to DMAP No. 28 if no stiffness matrix is to be assembled.

27. EMA assembles stiffness matrix $[K^x_{gg}]$ and Grid Point Singularity Table.

29. Go to DMAP No. 90 and print Error Message No. 1 if no mass matrix is to be assembled.

30. EMA assembles mass matrix $[M_{gg}]$.

31. Go to DMAP No. 34 if no weight and balance information is requested.

32. GPWG generates weight and balance information.

33. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

35. Equivalence $[K^x_{gg}]$ to $[K_{gg}]$ if there are no general elements.

36. Go to DMAP No. 38 if there are no general elements.

37. SMA3 adds general elements to $[K^x_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

40. GP4 generates flags defining members of various displacement sets (USET), forms multipoint constraint equations $[R_g]\{u_g\} = 0$ and forms enforced displacement vector $\{Y_s\}$.

41. Go to DMAP No. 94 and print Error Message No. 3 if no independent degrees of freedom are defined.

43. Go to DMAP No. 96 and print Error Message No. 4 if free-body supports are present.

45. GPCYC prepares segment boundary table (CYCD).

46. Go to DMAP No. 98 and print Error Message No. 5 if CYJØIN data is inconsistent.

47. Go to DMAP No. 52 if general elements are present.

49. Go to DMAP No. 52 if no potential grid point singularities exist.

50. GPSP generates a table of potential grid point singularities.

51. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

53. Equivalence $[K_{gg}]$ to $[K_{nn}]$ and $[M_{gg}]$ to $[M_{nn}]$ if no multipoint constraints exist.

54. Go to DMAP No. 57 if no multipoint constraints exist.

55. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

56. MCE2 partitions stiffness matrix

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right]$$

and performs matrix reduction

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \quad .$$

58. Equivalence $[K_{nn}]$ to $[K_{ff}]$ and $[M_{nn}]$ to $[M_{ff}]$ if no single-point constraints exist.

59. Go to DMAP No. 61 if no single-point constraints exist.

60. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right] \quad \text{and} \quad [M_{nn}] = \left[\begin{array}{c|c} M_{ff} & M_{fs} \\ \hline M_{sf} & M_{ss} \end{array}\right] .$$

62. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

63. Equivalence $[M_{ff}]$ to $[M_{aa}]$ if no omitted coordinates exist.

64. Go to DMAP No. 67 if no omitted coordinates exist.

65. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right] ,$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

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66. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \left[\begin{array}{c|c} \bar{M}_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right] ,$$

and performs matrix reduction

$$[M_{aa}] = [\bar{M}_{aa}] + [M_{oa}^T][G_o] + [G_o^T][M_{oa}] + [G_o^T][M_{oo}][G_o] \ .$$

68. DPD extracts Eigenvalue Extraction Data from Dynamics data block.

69. Go to DMAP No. 92 and print Error Message No. 2 if there is no Eigenvalue Extraction Data.

70. CYCT2 transforms matrices from symmetric components to solution set by the equations

$$[K_{kk}] = [G_1^T][K_{aa}][G_1] + [G_2^T][K_{aa}[G_2] ,$$

and

$$[M_{kk}] = [G_1^T][M_{aa}][G_1] + [G_2^T][M_{aa}[G_2] ,$$

where $G_1 = G_c$ (cosine) and $G_2 = G_s$ (sine) for rotational symmetry,

and $G_1 = G_S$ (Symmetric) and $G_2 = G_A$ (Antisymmetric) for dihedral symmetry.

71. Go to DMAP No. 98 and print Error Message No. 5 if a CYCT2 error was found.

72. READ extracts real eigenvalues and eigenvectors from the equation

$$[K_{kk} - \lambda M_{kk}]\{u_k\} = 0 \ ,$$

calculates modal mass matrix

$$[m] = [\phi_k^T][M_{kk}][\phi_k]$$

and normalizes eigenvectors according to one of the following user requests:

1) Unit value of a selected component
2) Unit value of the largest component
3) Unit value of the generalized mass.

73. ØFP formats the summary of eigenvalue extraction information (ØEIGS) prepared by READ and places it on the system output file for printing.

74. Go to DMAP No. 102 and make normal exit if no eigenvalues were found.

75. ØFP formats the eigenvalues (LAMK) prepared by READ and places them on the system output file for printing.

76. CYCT2 finds symmetric components of eigenvectors from solution set eigenvectors.

77. Go to DMAP No. 98 and print Error Message No. 5 if a CYCT2 error was found.

78. SDR1 recovers dependent components of the eigenvectors

$$\{\phi_o\} = [G_o]\{\phi_a\} \quad , \qquad \left\{\frac{\phi_a}{\phi_o}\right\} = \{\phi_f\} \quad ,$$

$$\left\{\frac{\phi_f}{\phi_s}\right\} = \{\phi_n\} \quad , \qquad \{\phi_m\} = [G_m]\{\phi_n\} \quad ,$$

$$\left\{\frac{\phi_n}{\phi_m}\right\} = \{\phi_g\}$$

and recovers single-point forces of constraint $\{q_s\} = [K_{fs}]^T\{\phi_f\}$.

79. Go to DMAP No. 82 if no multipoint constraint force balance is requested.

80. EQMCK calculates the force and moment equilibrium check and prepares the multipoint constraint force balance (ØQM1) for output.

81. ØFP formats the table prepared by EQMCK and places it on the system output file for printing.

83. SDR2 calculates element forces (ØEF1) and stresses (ØES1) and prepares eigenvectors (ØPHIG) and single-point forces of constraint (ØQG1) for output and translation components of the eigenvectors (PPHIG).

84. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

85. Go to DMAP No. 88 if no deformed structure plots are requested.

86. PLØT generates all requested deformed structure and contour plots.

87. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.

89. Go to DMAP No. 102 and make normal exit.

91. Print Error Message No. 1 and terminate execution.

93. Print Error Message No. 2 and terminate execution.

95. Print Error Message No. 3 and terminate execution.

97. Print Error Message No. 4 and terminate execution.

99. Print Error Message No. 5 and terminate execution.

101. Print Error Message No. 6 and terminate execution.

3.16.3 Output for Normal Modes Analysis Using Cyclic Symmetry

The Eigenvalue Summary Table and the Eigenvalue Analysis Summary, as described under Normal Mode Analysis (see Section 3.4.3), are automatically printed.

Each NASTRAN run calculates modes for only one symmetry index, k. The following output may be requested:

1. Eigenvectors along with the associated eigenvalue for each mode.
2. Nonzero components of the single-point forces of constraint for selected modes at selected grid points.
3. Forces and stresses in selected elements for selected modes.
4. Undeformed plot of the structural model and mode shapes for selected modes.
5. Contour plots of stresses and displacements for selected modes.

3.16.4 Case Control Deck for Normal Modes Analysis Using Cyclic Symmetry

The following items relate to subcase definition and data selection for Normal Modes Analysis Using Cyclic Symmetry:

1. METHØD must be used to select an EIGR card that exists in the Bulk Data Deck.
2. An SPC set must be selected unless the model is a free body or all constraints are specified on GRID cards, Scalar Connection cards or with General Elements.
3. Multiple subcases are used only to control output requests. A single subcase is sufficient if the same output is desired for all modes. If multiple subcases are present, the output requests will be honored in succession for increasing mode numbers. MØDES may be used to repeat subcases in order to make the same output request for several consecutive modes.

3.16.5 Parameters for Normal Modes Analysis Using Cyclic Symmetry

The following parameters are used in Normal Modes Analysis Using Cyclic Symmetry:

1. GRDPNT - optional. A positive integer value of this parameter will cause the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
2. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in EMA. Not recommended for use in hydroelastic problems.

3. COUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters will cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.

4. CTYPE - required. The BCD value of this parameter defines the type of cyclic symmetry as follows:

   (1) RØT - rotational symmetry

   (2) DRL - dihedral symmetry, using right and left halves

   (3) DSA - dihedral symmetry, using symmetric and antisymmetric components

5. NSEGS - required. The integer value of this parameter is the number of identical segments in the structural model.

6. CYCSEQ - optional. The integer value of this parameter specifies the procedure for sequencing the equations in the solution set. A value of +1 specifies that all cosine terms should be sequenced before all sine terms, and a value of -1 for alternating the cosine and sine terms. The default value is -1.

7. KINDEX - required. The integer value of this parameter specifies a single value of the harmonic index.

8. ØPT - optional. A positive integer value of this parameter causes both equilibrium and multipoint constraint forces to be calculated for the Case Control output request, MPCFØRCE. A negative integer value of this parameter causes only the equilibrium force balance to be calculated for the output request. The default value is 0 which causes only the multipoint constraint forces to be calculated for the output request.

9. GRDEQ - optional. A positive integer value of this parameter selects the grid point about which equilibrium will be checked for the Case Control output request, MPCFØRCE. If the integer value is zero, the basic origin is used. Default is -1.

10. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.

11. AUTØSPC - reserved for future optional use. The default value is -1.

3.16.6 Optional Diagnostic Output for FEER

Special detailed information obtained by requesting DIAG 16 in the Executive Control Deck is the same as that described under Normal Mode Analysis (see Section 3.4.6).

3.16.7 The APPEND Feature

The APPEND feature can be used for real eigenvalue extraction in Normal Modes Analysis Using Cyclic Symmetry. See Section 3.4.7 for details.

3.16.8 Rigid Format Error Messages from Normal Modes Analysis Using Cyclic Symmetry

The following fatal errors are detected by the DMAP statements in the Normal Modes Analysis Using Cyclic Symmetry rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

NØRMAL MØDES WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 1 - MASS MATRIX REQUIRED FØR REAL EIGENVALUE ANALYSIS.

The mass matrix is null because either no elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

NØRMAL MØDES WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 2 - EIGENVALUE EXTRACTIØN DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGR card in the Bulk Data Deck and METHOD in the Case Control Deck must select an EIGR set.

NØRMAL MØDES WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 3 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT, or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, SUPØRT, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

NØRMAL MØDES WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 4 - FREE BØDY SUPPØRTS NØT ALLØWED.

Free bodies are not allowed in Normal Modes Analysis Using Cyclic Symmetry. The SUPØRT cards must be removed from the Bulk Data Deck and other constraints applied if required for stability.

NØRMAL MØDES WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 5 - CYCLIC TRANSFØRMATIØN DATA ERRØR.

See Section 1.12 for proper modeling techniques and corresponding PARAM card requirements.

NØRMAL MØDES WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 6 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

3.17 STATIC HEAT TRANSFER ANALYSIS

3.17.1 DMAP Sequence for Static Heat Transfer Analysis

```
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HEAT APPROACH, RIGID FORMAT 1

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OPTIONS IN EFFECT   GO     ERR=2   LIST    NODECK  NOREF   NOOSCAR

   1  BEGIN     HEAT 01 - STATIC HEAT TRANSFER ANALYSIS - APR. 1984 $
   2  PRECHK    ALL $
   3  FILE      HQG=APPEND/HPGG=APPEND/HUGV=APPEND/HGM=SAVE/HKNN=SAVE $
   4  PARAM     //*MPY*/CARDNO/0/0 $
   5  GP1       GEOM1,GEOM2,/GPL,HEQEXIN,GPDT,CSTM,BGPDT,HSIL/S,N,HLUSET/
                NOGPDT/MINUS1=-1 $
   6  PLTTRAN   BGPDT,HSIL/BGPDP,HSIP/HLUSET/S,N,HLUSEP $
   7  GP2       GEOM2,HEQEXIN/ECT $
   8  PARAML    PCDB//*PRES*////JUMPPLOT $
   9  PURGE     PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $
  10  COND      HP1,JUMPPLOT $
  11  PLTSET    PCDB,HEQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,HNSIL/ S,N,
                JUMPPLOT $
  12  PRTMSG    PLTSETX// $
  13  PARAM     //*MPY*/PLTFLG/1/1 $
  14  PARAM     //*MPY*/PFILE/0/0 $
  15  COND      HP1,JUMPPLOT $
  16  PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,HEQEXIN,HSIL,,ECT,,/PLOTX1/
                HNSIL/HLUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $
  17  PRTMSG    PLOTX1// $
  18  LABEL     HP1 $
  19  GP3       GEOM3,HEQEXIN,GEOM2/HSLT,GPTT/NOGRAV $
  20  TA1       ECT,EPT,BGPDT,HSIL,GPTT,CSTM/HEST,,HGPECT,,/HLUSET/S,N,NOSIMP/
                1/NOGENL/GENEL $
  21  COND      ERROR4,NOSIMP $
  22  PURGE     HKGG,GPST/NOSIMP $
  23  COND      HLBL1,NOSIMP $
  24  PARAM     //*ADD*/HNOKGG/1/0 $
  25  EMG       HEST,CSTM,MPT,DIT,GEOM2,/HKELM,HKDICT,...,/S,N,HNOKGG $
  26  PURGE     HKGG,GPST/HNOKGG $
  27  COND      HLBL1,HNOKGG $
  28  EMA       HGPECT,HKDICT,HKELM/HKGG,GPST $
  29  LABEL     HLBL1 $
  30  PARAM     //*MPY*/NSKIP/0/0 $
```

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HEAT APPROACH, RIGID FORMAT 1

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Top of Constraints Loop

```
31  LABEL   HLBL11 $
32  GP4     CASECC,GEOM4,HEQEXIN,GPDT,BGPDT,CSTM,GPST/RG,YS,HUSET,HASET/
            HLUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/    S,
            N,NSKIP/S,N,HREPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/S,Y,
            AUTOSPC $
33  COND    ERROR3,NOL $
34  PARAM   //*AND*/NOSR/SINGLE/REACT $
35  PURGE   HKRR,HKLR,HQR,HDM/REACT/GM/MPCF1/HGO,HKOO,HLOO,HPO,HUOOV,
            HRUOV/OMIT/HPS,HKFS,HKSS/SINGLE/HQG/NOSR $
36  PARAM   //*EQ*/GPSPFLG/AUTOSPC/0 $
37  COND    HLBL4,GPSPFLG $
38  GPSP    GPL,GPST,HUSET,HSIL/OGPST/S,N,NOGPST $
39  OFP     OGPST,,,,,//S,N,CARDNO $
40  LABEL   HLBL4 $
41  EQUIV   HKGG,HKNN/MPCF1 $
42  COND    HLBL2,MPCF1 $
43  MCE1    HUSET,RG/GM $
44  MCE2    HUSET,GM,HKGG,,,/HKNN,,, $
45  LABEL   HLBL2 $
46  EQUIV   HKNN,HKFF/SINGLE $
47  COND    HLBL3,SINGLE $
48  SCE1    HUSET,HKNN,,,/HKFF,HKFS,HKSS,,, $
49  LABEL   HLBL3 $
50  EQUIV   HKFF,HKAA/OMIT $
51  COND    HLBL5,OMIT $
52  SMP1    HUSET,HKFF,,,/HGO,HKAA,HKOO,HLOO,,,,, $
53  LABEL   HLBL5 $
54  EQUIV   HKAA,HKLL/REACT $
55  COND    HLBL6,REACT $
56  RBMG1   HUSET,HKAA,/HKLL,HKLR,HKRR,,, $
57  LABEL   HLBL6 $
58  RBMG2   HKLL/HLLL $
59  COND    HLBL7,REACT $
60  RBMG3   HLLL,HKLR,HKRR/HDM $
61  LABEL   HLBL7 $
62  SSG1    HSLT,BGPDT,CSTM,HSIL,HEST,MPT,GPTT,EDT,,CASECC,DIT,/HPG,,,,/HLUSET/
            NSKIP $
63  EQUIV   HPG,HPL/NOSET $
64  COND    HLBL10,NOSET $
```

RIGID FORMAT DMAP LISTING
RELEASE APR. 1984

HEAT APPROACH, RIGID FORMAT 1

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
65  SSG2     HUSET,GM,YS,HKFS,HGO,HDM,HPG/HQR,HPO,HPS,HPL $
66  LABEL    HLBL10 $
67  SSG3     HLLL,HKLL,HPL,HLOO,HKOO,HPO/HULV,HUOOV,HRULV,HRUOV/OMIT/   V,Y,
             IRES=-1/NSKIP/S,N,EPSI $
68  COND     HLBL9,IRES $
69  MATGPR   GPL,HUSET,HSIL,HRULV//*L* $
70  MATGPR   GPL,HUSET,HSIL,HRUOV//*O* $
71  LABEL    HLBL9 $
72  SDR1     HUSET,HPG,HULV,HUOOV,YS,HGO,GM,HPS,HKFS,HKSS,HQR/HUGV,HPGG,HQG/
             NSKIP/*HSTATICS* $
73  COND     HLBL8,HREPEAT $
74  REPT     HLBL11,100 $
--------------------------------------   Bottom of Constraints Loop
75  JUMP     ERROR1 $
76  PARAM    //*NOT*/HTEST/HREPEAT $
77  COND     ERROR5,HTEST $
78  LABEL    HLBL8 $
79  SDR2     CASECC,CSTM,MPT,DIT,HEQEXIN,HSIL,GPTT,EDT,BGPDP,,HQG,HUGV,
             HEST,,HPGG/HOPG1,HOQG1,HOUGV1,,HOEF1,HPUGV1/*STATICS* $
80  OFP      HOUGV1,HOPG1,HOQG1,HOEF1,,//S,N,CARDNO $
81  COND     HP2,JUMPPLOT $
82  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,HEQEXIN,HSIP,HPUGV1,,HGPECT,
             /PLOTX2/HNSIL/HLUSEP/JUMPPLOT/PLTFLG/   S,N,PFILE $
83  PRTMSG   PLOTX2// $
84  LABEL    HP2 $
85  JUMP     FINIS $
86  LABEL    ERROR1 $
87  PRTPARM  //-1/*HSTA* $
88  LABEL    ERROR3 $
89  PRTPARM  //-3/*HSTA* $
90  LABEL    ERROR4 $
91  PRTPARM  //-4/*HSTA* $
92  LABEL    ERROR5 $
93  PRTPARM  //-5/*HSTA* $
94  LABEL    FINIS $
95  PURGE    DUMMY/MINUS1 $
96  END      $
```

3.17.2 Description of DMAP Operations for Static Heat Transfer Analysis

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external degree of freedom indices.

6. PLTTRAN modifies special scalar grid points in the BGPDT and HSIL tables.

7. GP2 generates Element Connection Table with internal indices.

10. Go To DMAP No. 18 if there are no structure plot requests.

11. PLTSET transforms user input into a form used to drive the structure plotter.

12. PRTMSG prints error messages associated with the structure plotter.

15. Go to DMAP No. 18 if no boundary and structure (heat conduction) element plots are requested.

16. PLØT generates a l requested boundary and heat conduction element plots.

17. PRTMSG prints plotter data and engineering data for each plot generated.

19. GP3 generates applied Static (Thermal) Loads Table (HSLT) and Grid Point Temperature Table.

20. TA1 generates element tables for use in matrix assembly, load generation, and data recovery.

21. Go to DMAP No. 90 and print Error Message No. 4 if no elements have been defined.

23. Go to DMAP No. 29 if there are no heat conduction elements.

25. EMG generates element heat conduction matrix tables and dictionaries for later assembly by the EMA module.

27. Go to DMAP No. 29 if no heat conduction matrix is to be assembled.

28. EMA assembles heat conduction matrix $[K^x_{gg}]$ and Grid Point Singularity Table.

31. Beginning of loop for additional constraint sets.

32. GP4 generates flags defining members of various displacement sets (USET), forms multipoint constraint equations $[R_g]\{u_g\} = 0$ and forms enforced displacement vector $\{Y_s\}$.

33. Go to DMAP No. 88 and print Error Message No. 3 if no independent degrees of freedom are defined.

37. Go to DMAP No. 40 if no potential grid point singularities exist.

38. GPSP generates a table of potential grid point singularities.

39. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

41. Equivalence $[K_{gg}]$ to $[K_{nn}]$ if no multipoint constraints exist.

42. Go to DMAP No. 45 if no multipoint constraints exist.

43. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

44. MCE2 partitions heat conduction matrix

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right]$$

and performs matrix reduction

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m].$$

46. Equivalence $[K_{nn}]$ to $[K_{ff}]$ if no single-point constraints exist.

47. Go to DMAP No. 49 if no single-point constraints exist.

48. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right].$$

50. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

51. Go to DMAP No. 53 if no omitted coordinates exist.

52. SMP1 partitions constrained heat conduction matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right],$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

54. Equivalence $[K_{aa}]$ to $[K_{\ell\ell}]$ if no free-body supports exist.

55. Go to DMAP No. 57 if no free-body supports exist.

56. RBMG1 partitions out free-body supports

$$[K_{aa}] = \left[\begin{array}{c|c} K_{\ell\ell} & K_{\ell r} \\ \hline K_{r\ell} & K_{rr} \end{array}\right].$$

58. RBMG2 decomposes constrained heat conduction matrix $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$.

59. Go to DMAP No. 61 if no free-body supports exist.

60. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}] \quad ,$$

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D]$$

and calculates rigid body error ratio

$$\varepsilon = \frac{||X||}{||K_{rr}||} .$$

62. SSG1 generates static thermal load vectors $\{P_g\}$.

63. Equivalence $\{P_g\}$ to $\{P_\ell\}$ if no constraints are applied.

64. Go to DMAP No. 66 if no constraints are applied.

65. SSG2 applies constraints to static thermal load vectors

$$\{P_g\} = \left\{\frac{\bar{P}_n}{P_m}\right\} , \quad \{P_n\} = \{\bar{P}_n\} + [G_m^T]\{P_m\} ,$$

$$\{P_n\} = \left\{\frac{\bar{P}_f}{P_s}\right\} , \quad \{P_f\} = \{\bar{P}_f\} - [K_{fs}]\{Y_s\} ,$$

$$\{P_f\} = \left\{\frac{\bar{P}_a}{P_o}\right\} , \quad \{P_a\} = \{\bar{P}_a\} + [G_o^T]\{P_o\} ,$$

$$\{P_a\} = \left\{\frac{P_\ell}{P_r}\right\}$$

and calculates determinate thermal powers $\{q_r\} = -\{P_r\} - [D^T]\{P_\ell\}$.

67. SSG3 solves for displacements of independent coordinates

$$\{u_\ell\} = [K_{\ell\ell}]^{-1}\{P_\ell\} ,$$

solves for displacements of omitted coordinates

$$\{u_o^o\} = [K_{oo}]^{-1}\{P_o\} ,$$

calculates residual vector (HRULV) and residual vector error ratio for independent coordinates

$$\{\delta P_\ell\} = \{P_\ell\} - [K_{\ell\ell}]\{u_\ell\} ,$$

$$\varepsilon_\ell = \frac{\{u_\ell^T\}\{\delta P_\ell\}}{\{P_\ell^T\}\{u_\ell\}}$$

and calculates residual vector (HRUØV) and residual vector error ratio for omitted coordinates

$$\{\delta P_o\} = \{P_o\} - [K_{oo}]\{u_o^o\} \quad ,$$

$$\varepsilon_o = \frac{\{u_o^T\}\{\delta P_o\}}{\{P_o^T\}\{u_o^o\}}$$

68. Go to DMAP No. 71 if residual vectors are not to be printed.

69. MATGPR prints the residual vector for independent coordinates (HRULV).

70. MATGPR prints the residual vector for omitted coordinates (HRUØV).

72. SDR1 recovers dependent temperatures

$$\left\{\begin{array}{c} u_\ell \\ \hline u_r \end{array}\right\} = \{u_a\} \ , \qquad \{u_o\} = [G_o]\{u_a\} + \{u_o^o\} \quad ,$$

$$\left\{\begin{array}{c} u_a \\ \hline u_o \end{array}\right\} = \{u_f\} \ , \qquad \left\{\begin{array}{c} u_f \\ \hline Y_s \end{array}\right\} = \{u_n\} \quad ,$$

$$\{u_m\} = [G_m]\{u_n\} \ , \qquad \left\{\begin{array}{c} u_n \\ \hline u_m \end{array}\right\} = \{u_g\}$$

and recovers single-point powers of sustained thermal constraint

$$\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\} + [K_{ss}]\{Y_s\}.$$

73. Go to DMAP No. 78 if all constraint sets have been processed.

74. Go to DMAP No. 31 if additional sets of constraints need to be processed.

75. Go to DMAP No. 86 and print Error Message No. 1 as the number of constraint sets exceeds 100.

77. Go to DMAP No. 92 and print Error Message No. 5 if multiple boundary conditions are attempted with an improper subset.

79. SDR2 calculates conduction and boundary element heat flows and gradients (HØEF1) and prepares thermal load vectors (HØPG1), temperature vectors (HØUGV1) and single-point powers of constraint (HØQG1) for output and components of the temperature vector (HPUGV1).

80. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

81. Go to DMAP No. 84 if no temperature profile plots are requested.

82. PLØT generates all requested temperature profile and thermal contour plots.

83. PRTMSG prints plotter data, engineering data, and contour data for each temperature profile and thermal contour plot generated.

85. Go to DMAP No. 94 and make normal exit.

87. Print Error Message No. 1 and terminate execution.

89. Print Error Message No. 3 and terminate execution.

91. Print Error Message No. 4 and terminate execution.

93. Print Error Message No. 5 and terminate execution.

3.17.3 Output for Static Heat Transfer Analysis

The following output may be requested for Static Heat Transfer Analysis:

1. Temperatures (THERMAL) and nonzero components of static loads (ØLØAD) and constrained heat flow (SPCFØRCE) at selected grid points or scalar points.
2. The punch option of a THERMAL request will produce TEMP bulk data cards.
3. Flux density (ELFØRCE) in selected elements.
4. Plots of the structural model and temperature profiles.
5. Contour plots of the thermal field.

3.17.4 Case Control Deck for Static Heat Transfer Analysis

The following items relate to subcase definition and data selection for Static Heat Transfer Analysis:

1. A separate subcase must be defined for each unique combination of constraints and static loads.
2. A static loading condition must be defined for (not necessarily within) each subcase with a LØAD selection, unless all loading is specified with grid point temperatures on SPC cards.
3. An SPC set must be selected for (not necessarily within) each subcase, unless all constraints are specified on GRID cards or Scalar Connection cards.
4. Loading conditions associated with the same sets of constraints should be in contiguous subcases, in order to avoid unnecessary looping.
5. REPCASE may be used to repeat subcases in order to allow multiple sets of the same output item.

3.17.5 Parameters for Static Heat Transfer Analysis

The following parameters are used in Static Heat Transfer Analysis:

1. IRES - optional. A positive integer value of this parameter will cause the printing of the residual vectors following the execution of SSG3.
2. ASETØUT - optional. A positive integer value of this parameter causes the HASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
3. AUTØSPC - reserved for future optional use. The default value is -1.

3.17.6 Rigid Format Error Messages from Static Heat Transfer Analysis

The following fatal errors are detected by the DMAP statements in the Static Heat Transfer Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

STATIC HEAT TRANSFER ANALYSIS ERRØR MESSAGE NØ. 1 - ATTEMPT TØ EXECUTE MØRE THAN 100 LØØPS.

An attempt has been made to use more than 100 different sets of boundary conditions. This number may be increased by ALTERing the REPT instruction following SDR1.

STATIC HEAT TRANSFER ANALYSIS ERRØR MESSAGE NØ. 3 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, SUPØRT, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

STATIC HEAT TRANSFER ANALYSIS ERRØR MESSAGE NØ. 4 - NØ ELEMENTS HAVE BEEN DEFINED.

No elements have been defined with either Connection cards or GENEL cards.

STATIC HEAT TRANSFER ANALYSIS ERRØR MESSAGE NØ. 5 - A LØØPING PRØBLEM RUN ØN A NØN-LØØPING SUBSET.

A problem requiring boundary condition changes was run on subset 1 or 3. The problem should be restarted on subset 0.

3.18 NONLINEAR STATIC HEAT TRANSFER ANALYSIS

3.18.1 DMAP Sequence for Nonlinear Static Heat Transfer Analysis

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RIGID FORMAT DMAP LISTING
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HEAT APPROACH, RIGID FORMAT 3

     LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

OPTIONS IN EFFECT   GO     ERR=2   LIST   NODECK  NOREF   NOOSCAR

   1  BEGIN    HEAT 03 - NONLINEAR STATIC HEAT TRANSFER ANALYSIS - APR. 1984 $
   2  PRECHK   ALL $
   3  PARAM    //*MPY*/CARDNO/0/0 $
   4  GP1      GEOM1,GEOM2,/GPL,HEQEXIN,GPDT,CSTM,BGPDT,HSIL/S,N,HLUSET/
               NOGPDT/MINUS1=-1 $
   5  PLTTRAN  BGPDT,HSIL/BGPDP,HSIP/HLUSET/S,N,HLUSEP $
   6  GP2      GEOM2,HEQEXIN/ECT $
   7  PARAML   PCDB//*PRES*////JUMPPLOT $
   8  PURGE    PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $
   9  COND     HP1,JUMPPLOT $
  10  PLTSET   PCDB,HEQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,HNSIL/ S,N,
               JUMPPLOT $
  11  PRTMSG   PLTSETX// $
  12  PARAM    //*MPY*/PLTFLG/1/1 $
  13  PARAM    //*MPY*/PFILE/0/0 $
  14  COND     HP1,JUMPPLOT $
  15  PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,HEQEXIN,HSIL,,ECT,,/PLOTX1/
               HNSIL/HLUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $
  16  PRTMSG   PLOTX1// $
  17  LABEL    HP1 $
  18  GP3      GEOM3,HEQEXIN,GEOM2/HSLT,GPTT/NOGRAV $
  19  TA1      ECT,EPT,BGPDT,HSIL,GPTT,CSTM/HEST,,HGPECT,,/HLUSET/S,N,NOSIMP/
               1/NOGENL/HXYZ $
  20  COND     ERROR2,NOSIMP $
  21  PARAM    //*ADD*/HNOKGG/1/0 $
  22  EMG      HEST,CSTM,MPT,DIT,GEOM2,/HKELM,HKDICT,,,,/S,N,HNOKGG $
  23  PURGE    HKGGX,GPST/HNOKGG$
  24  COND     JMPKGGX,HNOKGG $
  25  EMA      HGPECT,HKDICT,HKELM/HKGGX,GPST $
  26  LABEL    JMPKGGX $
  27  RMG      HEST,MATPOOL,GPTT,HKGGX/HRGG,HQGE,HKGG/C,Y,TABS/C,Y,SIGMA=0.0/
               S,N,HNLR/HLUSET $
  28  EQUIV    HKGGX,HKGG/HNLR $
  29  PURGE    HQGE,HRGG/HNLR $
  30  GP4      CASECC,GEOM4,HEQEXIN,GPDT,BGPDT,CSTM,GPST/RG,YS,HUSET,HASET/
```


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HEAT APPROACH, RIGID FORMAT 3

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
              HLUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/    S,
              N,NSKIP/S,N,HREPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/S,Y,
              AUTOSPC $

 31  COND     ERROR1,NOL $

 32  PURGE    GM/MPCF1/HPS,HKFS,HKSS,HKSF,HRSN,HQG/SINGLE $

 33  PARAM    //*EQ*/GPSPFLG/AUTOSPC/0 $

 34  COND     HLBL5,GPSPFLG $

 35  GPSP     GPL,GPST,HUSET,HSIL/OGPST/S,N,NOGPST $

 36  OFP      OGPST,,,,,//S,N,CARDNO $

 37  LABEL    HLBL5 $

 38  EQUIV    HKGG,HKNN/MPCF1/HRGG,HRNN/MPCF1 $

 39  COND     HLBL1,MPCF1 $

 40  MCE1     HUSET,RG/GM $

 41  MCE2     HUSET,GM,HKGG,HRGG,,/HKNN,HRNN,, $

 42  LABEL    HLBL1 $

 43  EQUIV    HKNN,HKFF/SINGLE/HRNN,HRFN/SINGLE $

 44  COND     HLBL2,SINGLE $

 45  VEC      HUSET/VFS/*N*/*F*/*S* $

 46  PARTN    HKNN,VFS,/HKFF,HKSF,HKFS,HKSS $

 47  PARTN    HRNN,,VFS/HRFN,HRSN,,/1 $

 48  LABEL    HLBL2 $

 49  DECOMP   HKFF/HLLL,HULL/0/0/MDIAG/DET/PWR/S,N,KSING $

 50  COND     ERROR3,KSING $

 51  SSG1     HSLT,BGPDT,CSTM,HSIL,HEST,MPT,GPTT,EDT,,CASECC,DIT,/HPG,,,,/HLUSET/
              NSKIP $

 52  EQUIV    HPG,HPF/NOSET $

 53  COND     HLBL3,NOSET $

 54  SSG2     HUSET,GM,,HKFS,,,HPG/,,HPS,HPF $

 55  LABEL    HLBL3 $

 56  SSGHT    HUSET,HSIL,GPTT,GM,HEST,MPT,DIT,HPF,HPS,HKFF,HKFS,HKSF,    HKSS,
              HRFN,HRSN,HLLL,HULL/HUGV,HQG,HRULV/HNNLK=1/HNLR/    C,Y,EPSHT=
              .001/C,Y,TABS=0.0/C,Y,MAXIT=4/V,Y,IRES/    MPCF1/SINGLE $

 57  COND     HLBL4,IRES $

 58  MATGPR   GPL,HUSET,HSIL,HRULV//*F* $

 59  LABEL    HLBL4 $

 60  SDR2     CASECC,CSTM,MPT,DIT,HEQEXIN,HSIL,GPTT,EDT,BGPDP,,HQG,HUGV,HEST,
              ,    HPG/HOPG1,HOQG1,HOUGV1,,HOEF1,HPUGV1/*STATICS* $

 61  OFP      HOUGV1,HOPG1,HOQG1,,,//S,N,CARDNO $

 62  SDRHT    HSIL,HUSET,HUGV,HOEF1,HSLT,HEST,DIT,HGGE,,/HOEF1X/C,Y,TABS/
              HNLR $

 63  OFP      HOEF1X,,,,,//S,N,CARDNO $
```


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HEAT APPROACH, RIGID FORMAT 3

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
64  COND      HP2,JUMPPLOT $
65  PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,HEQEXIN,HSIP,HPUGV1,,HGPECT,
              /PLOTX2/HNSIL/HLUSEP/JUMPPLOT/PLTFLG/   PFILE $
66  PRTMSG    PLOTX2// $
67  LABEL     HP2 $
68  JUMP      FINIS$
69  LABEL     ERROR1 $
70  PRTPARM   //-1/*HNLI* $
71  LABEL     ERROR2 $
72  PRTPARM   //-2/*HNLI* $
73  LABEL     ERROR3 $
74  PRTPARM   //-3/*HNLI* $
75  LABEL     FINIS$
76  PURGE     DUMMY/MINUS1 $
77  END       $
```

3.18.2 Description of DMAP Operations for Nonlinear Static Heat Transfer Analysis

4. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external degree of freedom indices.

5. PLTTRAN modifies special scalar grid points in the BGPDT and HSIL tables.

6. GP2 generates the Element Connection Table with internal indices.

9. Go to DMAP No. 17 if there are no structure plot requests.

10. PLTSET transforms user input into a form used to drive the structure plotter.

11. PRTMSG prints error messages associated with the structure plotter.

14. Go to DMAP No. 17 if no boundary and structure (heat conduction) element plots are requested.

15. PLØT generates all requested boundary and heat conduction element plots.

16. PRTMSG prints plotter and engineering data for each generated plot.

18. GP3 generates applied Static (Heat Flux) Loads Table (HSLT) and the Grid Point Temperature Table.

19. TA1 generates element tables for use in matrix assembly, load generation, and heat flux data recovery.

20. Go to DMAP No. 71 and print Error Message No. 2 if no elements have been defined.

22. EMG generates element heat conduction matrix tables and dictionaries for later assembly by the EMA module.

24. Go to DMAP No. 26 if no heat conduction matrix is to be assembled.

25. EMA assembles heat conduction matrix $[K^x_{gg}]$ and Grid Point Singularity Table.

27. RMG generates the radiation matrix, $[R_{gg}]$, and adds the estimated linear component of radiation to the heat conduction matrix. The element radiation flux matrix, $[Q_{ge}]$, is also generated for use in recovery data for the HBDY elements.

28. Equivalence $[K^x_{gg}]$ to $[K_{gg}]$ if there is no linear component of radiation.

30. GP4 generates flags defining members of various displacement sets (HUSET) and forms multipoint constraint equations $[R_g]\{u_g\} = \{0\}$.

31. Go to DMAP No. 69 and print Error Message No. 1 if no independent degrees of freedom are defined.

34. Go to DMAP No. 37 if no potential grid point singularities exist.

35. GPSP generates a table of potential grid point singularities. These singularities may be extraneous in a radiation problem, since some points may transfer heat through radiation only.

36. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

38. Equivalence $[K_{gg}]$ to $[K_{nn}]$ and $[R_{gg}]$ to $[R_{nn}]$ if no multipoint constraints exist.

39. Go to DMAP No. 42 if no multipoint constraints exist.

40. MCE1 partitions the multipoint constraint equation matrix $[R_g] = [R_m \mid R_n]$ and solves for the multipoint constraint transformation matrix

$$[G_m] = -[R_m]^{-1} [R_n] .$$

41. MCE2 partitions heat conduction and radiation matrices

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right] \quad \text{and} \quad [R_{gg}] = \left[\begin{array}{c|c} \bar{R}_{nn} & R_{nm} \\ \hline R_{mn} & R_{mm} \end{array}\right]$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \text{ and}$$

$$[R_{nn}] = [\bar{R}_{nn}] + [G_m^T][R_{mn}] + [R_{mn}^T][G_m] + [G_m^T][R_{mm}][G_m].$$

43. Equivalence $[K_{nn}]$ to $[K_{ff}]$ and $[R_{nn}]$ to $[R_{fn}]$ if no single-point constraints exist.

44. Go to DMAP No. 48 if no single-point constraints exist.

45. VEC generates a partitioning vector $\{u_n\} \rightarrow \{u_f\} + \{u_s\}$.

46. PARTN partitions the heat conduction matrix

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{fs} & K_{ss} \end{array}\right] .$$

47. PARTN partitions the radiation matrix

$$[R_{nn}] = \left[\begin{array}{c} R_{fn} \\ \hline R_{sn} \end{array}\right] .$$

49. DECØMP decomposes the potentially unsymmetric matrix $[K_{ff}]$ into upper and lower triangular factors $[U_{\ell\ell}]$ and $[L_{\ell\ell}]$.

50. Go to DMAP No. 73 and print Error Message No. 3 if the matrix is singular.

51. SSG1 generates the input heat flux vector $\{P_g\}$.

52. Equivalence $\{P_g\}$ to $\{P_f\}$ if no constraints are applied.

53. Go to DMAP No. 55 if no constraints of any kind exist.

54. SSG2 reduces the heat flux vector

$$\{P_g\} = \left\{\begin{array}{c} \bar{P}_n \\ \hline P_m \end{array}\right\} ,$$

$$\{P_n\} = \{\bar{P}_n\} + [G_m^T] \{P_m\}$$

and $$\{P_n\} = \left\{ \frac{P_f}{P_s} \right\} .$$

56. SSGHT solves the nonlinear heat transfer problem by an iteration technique which is limited by parameters EPSHT and MAXIT. The output data blocks are: $\{u_g\}$, the solution temperature vector, $\{q_g\}$, the heat flux due to single-point constraints, and $\{\delta P_\ell\}$, the matrix of residual heat fluxes at each iteration step.

57. Go to DMAP No. 59 if residual vectors are not to be printed.

58. MATGPR prints the residual vectors for independent coordinates (HRULV).

60. SDR2 calculates the heat flux due to conduction and convection in the elements (HØEF1) and prepares the temperature vector (HØUGV1), the load vector (HØPG1), and the power of constraint (HØQG1) for output and components of the temperature vector (HPUGV1).

61. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

62. SDRHT processes the HBDY elements to produce heat flux into the elements (HØEF1X) due to convection, radiation, and applied flux.

63. ØFP formats the element flux table prepared by SDRHT and places it on the system output file for printing.

64. Go to DMAP No. 67 if no temperature profile plots are requested.

65. PLØT generates all requested temperature profile and thermal contour plots.

66. PRTMSG prints plotter data, engineering data, and contour data for each temperature profile and thermal contour plot generated.

68. Go to DMAP No. 75 and make normal exit.

70. Print Error Message No. 1 and terminate execution.

72. Print Error Message No. 2 and terminate execution.

74. Print Error Message No. 3 and terminate execution.

3.18.3 Output for Nonlinear Static Heat Transfer Analysis

The following output may be requested for the last iteration in Nonlinear Static Heat Transfer Analysis:

1. Temperature (THERMAL) and nonzero components of static loads (ØLØAD) and constrained heat flow (SPCFØRCE) at selected grid points or scalar points.
2. The punch option of a THERMAL request will produce TEMP bulk data cards.
3. Flux density (ELFØRCE) in selected elements. In the case of CHBDY elements, a flux density summary is produced that includes applied flux, radiation flux, and convective flux.
4. Plots of the structural model and temperature profiles.
5. Contour plots of the thermal field.

3.18.4 Case Control Deck for Nonlinear Static Heat Transfer Analysis

The following items relate to subcase definition and data selection for Nonlinear Static Heat Transfer Analysis:

1. A single subcase must be defined with a single loading condition (LØAD) and a single constraint condition (SPC).
2. An estimated temperature distribution vector must be defined on TEMP cards and selected with a TEMP(MATERIAL) request. Temperatures for constrained components are taken from these TEMP cards and entries on SPC cards are ignored.

3.18.5 Parameters for Nonlinear Static Heat Transfer Analysis

The following parameters are used in Nonlinear Static Heat Transfer Analysis:

1. MAXIT - optional. The integer value of this parameter limits the maximum number of iterations. The default value is 4 iterations.
2. EPSHT - optional. The real value of this parameter is used to test the convergence of the solution. The default value is 0.001.
3. TABS - optional. The real value of this parameter is the absolute reference temperature. The default value is 0.0.
4. SIGMA - optional. The real value of this parameter is the Stefan-Boltzmann constant. The default value is 0.0.

5. IRES - optional. A positive integer value of this parameter will cause the printing of the residual vectors following the execution of SSGHT for each iteration.

6. ASETØUT - optional. A positive integer value of this parameter causes the HASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.

7. AUTØSPC - reserved for future optional use. The default value is -1.

3.18.6 Rigid Format Error Messages from Nonlinear Static Heat Transfer Analysis

The following fatal errors are detected by the DMAP statements in the Nonlinear Static Heat Transfer Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

NØNLINEAR STATIC HEAT TRANSFER ANALYSIS ERRØR MESSAGE NØ. 1 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, SUPØRT, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

NØNLINEAR STATIC HEAT TRANSFER ANALYSIS ERRØR MESSAGE NØ. 2 - NØ SIMPLE STRUCTURAL ELEMENTS.

No structural elements have been defined with Connection Cards.

NØNLINEAR STATIC HEAT TRANSFER ANALYSIS ERRØR MESSAGE NØ. 3 - STIFFNESS MATRIX SINGULAR.

The heat conduction matrix is singular due to unspecified grid point temperatures.

3.19 TRANSIENT HEAT TRANSFER ANALYSIS

3.19.1 DMAP Sequence for Transient Heat Transfer Analysis

```
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OPTIONS IN EFFECT   GO     ERR=2   LIST    NODECK  NOREF    NOOSCAR
-----------------

    1  BEGIN     HEAT 09 - TRANSIENT HEAT TRANSFER ANALYSIS - APR. 1984 $
    2  PRECHK    ALL $
    3  PARAM     //*MPY*/CARDNO/0/0 $
    4  GP1       GEOM1,GEOM2,/GPL,HEQEXIN,GPDT,CSTM,BGPDT,HSIL/S,N,HLUSET/    S,
                 N,NOGPDT/MINUS1=-1 $
    5  PLTTRAN   BGPDT,HSIL/BGPDP,HSIP/HLUSET/S,N,HLUSEP $
    6  PURGE     HUSET,GM,HGO,HKAA,HBAA,HPSO,HKFS,HQP,HEST/NOGPDT $
    7  COND      HLBL5,NOGPDT $
    8  GP2       GEOM2,HEQEXIN/ECT $
    9  PARAML    PCDB//*PRES*////JUMPPLOT $
   10  PURGE     PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $
   11  COND      HP1,JUMPPLOT $
   12  PLTSET    PCDB,HEQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,HNSIL/ S,N,
                 JUMPPLOT $
   13  PRTMSG    PLTSETX// $
   14  PARAM     //*MPY*/PLTFLG/1/1 $
   15  PARAM     //*MPY*/PFILE/0/0 $
   16  COND      HP1,JUMPPLOT$
   17  PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,HEQEXIN,HSIL,,ECT,,/PLOTX1/
                 HNSIL/HLUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $
   18  PRTMSG    PLOTX1// $
   19  LABEL     HP1 $
   20  GP3       GEOM3,HEQEXIN,GEOM2/HSLT,GPTT/1 $
   21  TA1       ECT,EPT,BGPDT,HSIL,GPTT,CSTM/HEST,,HGPECT,,/HLUSET/S,N,NOSIMP=
                 -1/1/123/123 $
   22  PURGE     HKGG,GPST,HBGG/NOSIMP $
   23  COND      HLBL1,NOSIMP $
   24  PARAM     //*ADD*/NOKGGX/1/0 $
   25  PARAM     //*ADD*/NOBGG/1/0 $
   26  EMG       HEST,CSTM,MPT,DIT,GEOM2,/HKELM,HKDICT,,,HBELM,HBDICT/S,N,
                 NOKGGX//S,N,NOBGG $
   27  PURGE     HKGGX,GPST/NOKGGX $
   28  COND      JMPKGGX,NOKGGX $
   29  EMA       HGPECT,HKDICT,HKELM/HKGGX,GPST $
   30  LABEL     JMPKGGX $
```

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 31  COND     JMPHBGG,NOBGG $
 32  EMA      HGPECT,HBDICT,HBELM/HBGG, $
 33  LABEL    JMPHBGG $
 34  PURGE    HBNN,HBFF,HBAA,HBGG/NOBGG $
 35  LABEL    HLBL1 $
 36  RMG      HEST,MATPOOL,GPTT,HKGGX/HRGG,HQGE,HKGG/C,Y,TABS/C,Y,SIGMA=0.0/
              S,N,HNLR/HLUSET $
 37  EQUIV    HKGGX,HKGG/HNLR $
 38  PURGE    HRGG,HRNN,HRFF,HRAA,HRDD/HNLR $
 39  GP4      CASECC,GEOM4,HEQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,HUSET,ASET/
              HLUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/ S,N,REACT/0/
              123/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/  S,Y,AUTOSPC $
 40  PURGE    GM,GMD/MPCF1/HGO,HGOD/OMIT/HKFS,HPSO,HQP/SINGLE $
 41  COND     HLBL2,NOSIMP $
 42  PARAM    //*EQ*/GPSPFLG/AUTOSPC/0 $
 43  COND     HLBL2,GPSPFLG $
 44  GPSP     GPL,GPST,HUSET,HSIL/OGPST/S,N,NOGPST $
 45  OFP      OGPST,,,,,//S,N,CARDNO $
 46  LABEL    HLBL2 $
 47  EQUIV    HKGG,HKNN/MPCF1/HRGG,HRNN/MPCF1/HBGG,HBNN/MPCF1 $
 48  COND     HLBL3,MPCF1 $
 49  MCE1     HUSET,RG/GM $
 50  MCE2     HUSET,GM,HKGG,HRGG,HBGG,/HKNN,HRNN,HBNN, $
 51  LABEL    HLBL3 $
 52  EQUIV    HKNN,HKFF/SINGLE/HRNN,HRFF/SINGLE/HBNN,HBFF/SINGLE $
 53  COND     HLBL4,SINGLE $
 54  SCE1     HUSET,HKNN,HRNN,HBNN,/HKFF,HKFS,,HRFF,HBFF, $
 55  LABEL    HLBL4 $
 56  EQUIV    HKFF,HKAA/OMIT $
 57  EQUIV    HRFF,HRAA/OMIT $
 58  EQUIV    HBFF,HBAA/OMIT $
 59  COND     HLBL5,OMIT $
 60  SMP1     HUSET,HKFF,,,/HGO,HKAA,HKOO,HLOO,,,,, $
 61  COND     HLBLR,HNLR $
 62  SMP2     HUSET,HGO,HRFF/HRAA $
 63  LABEL    HLBLR $
 64  COND     HLBL5,NOBGG $
 65  SMP2     HUSET,HGO,HBFF/HBAA $
```

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```
66  LABEL    HLBL5 $

67  DPD      DYNAMICS,GPL,HSIL,HUSET/GPLD,HSILD,HUSETD,TFPOOL,HDLT,,,HNLFT,
             HTRL,,HEQDYN/HLUSET/S,N,HLUSETD/123 /S,N,NODLT/    123/123/S,N,
             NONLFT/S,N,NOTRL/123//S,N,NOUE $

68  COND     ERROR1,NOTRL $

69  EQUIV    HGO,HGOD/NOUE/GM,GMD/NOUE $

70  PURGE    HPPO,HPSO,HPDO,HPDT/NODLT $

71  MTRXIN   CASECC,MATPOOL,HEQDYN,,TFPOOL/HK2PP,,HB2PP/HLUSETD/  S,N,
             NOK2PP/123/S,N,NOB2PP $

72  PARAM    //*AND*/KDEKA/NOUE/NOK2PP $

73  PURGE    HK2DD/NOK2PP/HB2DD/NOB2PP $

74  EQUIV    HKAA,HKDD/KDEKA/HB2PP,HB2DD/NOA/HK2PP,HK2DD/NOA/HRAA,HRDD/
             NOUE $

75  COND     HLBL6,NOGPDT $

76  GKAD     HUSETD,GM,HGO,HKAA,HBAA,HRAA,,HK2PP,,HB2PP/HKDD,HBDD,  HRDD,
             GMD,HGOD,HK2DD,HM2DD,HB2DD/*TRANRESP*/*DISP*/  *DIRECT*/C,Y,G=
             0.0/C,Y,W3=0.0/C,Y,W4=0.0/NOK2PP/-1/ NOB2PP/MPCF1/SINGLE/OMIT/
             NOUE/  -1/NOBGG/NOSIMP/-1 $

77  LABEL    HLBL6 $

78  EQUIV    HK2DD,HKDD/NOSIMP/HB2DD,HBDD/NOGPDT $

79  PARAM    //*MPY*/REPEATT/1/-1 $
                                                 Top of Dynamic Load Set Loop
80  LABEL    HLBL10 $

81  CASE     CASECC,/CASEXX/*TRAN*/S,N,REPEATT/S,N,NOLOOP $

82  TRLG     CASEXX,HUSETD,HDLT,HSLT,BGPDT,HSIL,CSTM,HTRL,DIT,GMD,HGOD,,
             HEST,/HPPO,HPSO,HPDO,HPDT,,HTOL/S,N,NOSET $

83  EQUIV    HPPO,HPDO/NOSET $

84  TRHT     CASEXX,HUSETD,HNLFT,DIT,GPTT,HKDD,HBDD,HRDD,HPDT,HTRL/ HUDVT,
             HPNLD/C,Y,BETA=.55/C,Y,TABS=0.0/HNLR/C,Y,RADLIN=-1 $

85  VDR      CASEXX,HEQDYN,HUSETD,HUDVT,HTOL,XYCDB,HPNLD/HOUDV1,HOPNL1/  *
             TRANRESP*/*DIRECT*/0/S,N,NOD/S,N,NOP/0 $

86  COND     HLBL7,NOD $

87  SDR3     HOUDV1,HOPNL1,,,,/HOUDV2,HOPNL2,,,, $

88  OFP      HOUDV2,HOPNL2,,,,//S,N,CARDNO $

89  XYTRAN   XYCDB,HOUDV2,HOPNL2,,,/HXYPLTTA/*TRAN*/*DSET*/S,N,HPFILE/S,N,
             HCARDNO $

90  XYPLOT   HXYPLTTA// $

91  LABEL    HLBL7 $

92  PARAM    //*AND*/PJUMP/NOP/JUMPPLOT $

93  COND     HLBL9,PJUMP $

94  EQUIV    HUDVT,HUPV/NOA $

95  COND     HLBL8,NOA $

96  SDR1     HUSETD,,HUDVT,,,HGOD,GMD,HPSO,HKFS,,/HUPV,,HQP/1/  *TRANSNT* $
```


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```
 97  LABEL    HLBL8 $
 98  SDR2     CASEXX,CSTM,MPT,DIT,HEQDYN,HSILD,,,BGPDP,HTOL,HQP,HUPV,HEST,
              XYCDB,HPPO/HOPP1,HOQP1,HOUPV1,,HOEF1,HPUGV/*TRANRESP* $
 99  SDRHT    HSILD,HUSETD,HUPV,HOEF1,ESLT,HEST,DIT,HQGE,HDLT,/HOEF1X/C,Y,
              TABS/HNLR $
100  EQUIV    HOEF1X,HOEF1/MINUS1 $
101  SDR3     HOPP1,HOQP1,HOUPV1,,HOEF1,/HOPP2,HOQP2,HOUPV2,,HOEF2, $
102  OFP      HOPP2,HOQP2,HOUPV2,HOEF2,,//S,N,CARDNO $
103  COND     HP2,JUMPPLOT $
104  PLOT     PLTPAR,GPSETS,ELSETS,CASEXX,BGPDT,HEQEXIN,HSIP,,HPUGV, HGPECT,/
              PLOTX2/HNSIL/HLUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $
105  PRTMSG   PLOTX2// $
106  LABEL    HP2 $
107  XYTRAN   XYCDB,HOPP2,HOQP2,HOUPV2,,HOEF2/HXYPLTT/*TRAN*/*PSET*/S,N,
              PFILE/S,N,CARDNO $
108  XYPLOT   HXYPLTT// $
109  LABEL    HLBL9 $
110  COND     FINIS,REPEATT $
111  REPT     HLBL10,100 $                 Bottom of Dynamic Load Set Loop
112  PRTPARM  //-2/*HTRD* $
113  JUMP     FINIS $
114  LABEL    ERROR1 $
115  PRTPARM  //-1/*HTRD* $
116  LABEL    FINIS$
117  PURGE    DUMMY/MINUS1 $
118  END      $
```

3.19.2 Description of DMAP Operations for Transient Heat Transfer Analysis

4. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external degree of freedom indices.

5. PLTTRAN modifies special scalar grid points in the BGPDT and HSIL tables.

7. Go to DMAP No. 66 if there is no Grid Point Definition Table.

8. GP2 generates the Element Connection Table with internal indices.

11. Go to DMAP No. 19 if there are no structure plot requests.

12. PLTSET transforms user input into a form used to drive the structure plotter.

13. PRTMSG prints error messages associated with the structure plotter.

16. Go to DMAP No. 19 if no boundary and structure (heat conduction) element plots are requested.

17. PLØT generates all requested boundary and heat conduction element plots.

18. PRTMSG prints plotter data and engineering data for each generated plot.

20. GP3 generates applied Static (Heat Flux) Load Tables (HSLT) and the Grid Point Temperature Table.

21. TA1 generates element tables for use in matrix assembly, load generation, and data recovery.

23. Go to DMAP No. 35 if no heat conduction or boundary elements exist.

26. EMG generates element heat conduction and capacitance matrix tables and dictionaries for later assembly by the EMA module.

28. Go to DMAP No. 30 if no heat conduction matrix is to be assembled.

29. EMA assembles heat conduction matrix $[K^x_{gg}]$ and Grid Point Singularity Table.

31. Go to DMAP No. 33 if no heat capacitance matrix is to be assembled.

32. EMA assembles heat capacitance matrix $[B_{gg}]$.

36. RMG generates the radiation matrix, $[R_{gg}]$, and adds the estimated linear component of radiation to the conductivity matrix. The element-radiation flux matrix, $[Q_{ge}]$, is also generated for use in data recovery.

37. Equivalence the linear heat transfer matrix, $[K_{gg}]$, to the heat conduction matrix if no radiation exists.

39. GP4 generates flags defining members of various displacement sets (HUSET) and forms the multipoint constraint equations, $[R_g]\{u_g\} = 0$.

41. Go to DMAP No. 46 if no simple elements exist.

43. Go to DMAP No. 46 if no potential grid point singularities exist.

44. GPSP generates a table of potential grid point singularities. These singularities may be extraneous in a radiation problem, since some points may transfer heat through radiation only.

45. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

47. Equivalence $[K_{gg}]$ to $[K_{nn}]$, $[R_{gg}]$ to $[R_{nn}]$, and $[B_{gg}]$ to $[B_{nn}]$ if no multipoint constraints exist.

48. Go to DMAP No. 51 if no multipoint constraints exist.

49. MCE1 partitions the multipoint constraint equation matrix, $[R_g] = [R_m \mid R_n]$, and solves for the multipoint constraint transformation matrix,

$$[G_m] = -[R_m]^{-1}\,[R_n]\ .$$

50. MCE2 partitions heat conduction and radiation matrices

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right] ,$$

$$[R_{gg}] = \left[\begin{array}{c|c} \bar{R}_{nn} & R_{nm} \\ \hline R_{mn} & R_{mm} \end{array}\right] ,$$

$$[B_{gg}] = \left[\begin{array}{c|c} \bar{B}_{nn} & B_{nm} \\ \hline B_{mn} & B_{mm} \end{array}\right] ,$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}][G_m] + [G_m^T][K_{mm}][G_m]\ .$$

The same equation is applied to $[R_{nn}]$ and $[B_{nn}]$.

52. Equivalence $[K_{nn}]$ to $[K_{ff}]$, $[B_{nn}]$ to $[B_{ff}]$, and $[R_{nn}]$ to $[R_{ff}]$ if no single-point constraints exist.

53. Go to DMAP No. 55 if no single-point constraints exist.

54. SCE1 partitions the matrices as follows:

$$[K_{nn}] = \left[\begin{array}{c|c} \bar{K}_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right] .$$

$[R_{nn}]$ and $[B_{nn}]$ are partitioned in the same manner, except that only the ff partitions are saved.

56. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates exist.

57. Equivalence $[R_{ff}]$ to $[R_{aa}]$ if no omitted coordinates exist.

58. Equivalence $[B_{ff}]$ to $[B_{aa}]$ if no omitted coordinates exist.

59. Go to DMAP No. 66 if no omitted coordinates exist.

60. SMP1 partitions the heat conduction matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right] ,$$

solves for the transformation matrix $[G_o]$:

$$[K_{oo}]\,[G_o] = -[K_{oa}] ,$$

and solves for the reduced heat conduction matrix $[K_{aa}]$:

$$[K_{aa}] = [\bar{K}_{aa}] + [K_{ao}]\,[G_o] .$$

61. Go to DMAP No. 63 if no radiation matrix exists.

62. SMP2 partitions constrained radiation matrix

$$[R_{ff}] = \left[\begin{array}{c|c} \bar{R}_{aa} & R_{ao} \\ \hline R_{oa} & R_{oo} \end{array}\right] ,$$

and performs matrix reduction

$$[R_{aa}] = [\bar{R}_{aa}] + [R_{oa}^T]\,[G_o] + [G_o^T]\,[R_{oa}] + [G_o^T]\,[R_{oo}]\,[G_o].$$

64. Go to DMAP No. 66 if no heat capacitance matrix, $[B_{ff}]$, exists.

65. SMP2 calculates a reduced heat capacitance matrix, $[B_{aa}]$, with the same equation as DMAP No. 62.

67. DPD generates the table defining the displacement sets each degree of freedom belongs to (HUSETD), including extra points. It prepares the Transfer Function Pool, the Dynamics Load Table, the Nonlinear Function Table, and the Transient Response List.

68. Go to DMAP No. 114 and print Error Message No. 1 if there is no Transient Response List.

69. Equivalence $[G_o]$ to $[G_o^d]$ and $[G_m]$ to $[G_m^d]$ if no extra points were defined.

71. MTRXIN selects the direct input matrices $[K_{pp}^2]$ and $[B_{pp}^2]$.

74. Equivalence $[K_{aa}]$ to $[K_{dd}^1]$ if there are no direct input stiffness matrices and no extra points; $[B_{pp}]$ to $[B_{dd}^2]$ and $[K_{pp}]$ to $[K_{dd}^2]$ if only extra points are used; and $[R_{aa}]$ to $[R_{dd}]$ if no extra points are used.

75. Go to DMAP No. 77 if there is no Grid Point Definition Table.

76. GKAD expands the matrices to include extra points and assembles heat conduction, capacitance, and radiation matrices for use in the transient analysis:

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$$[K^1_{dd}] = \left[\begin{array}{c|c} K_{aa} & 0 \\ \hline 0 & 0 \end{array}\right] ,$$

$$[B^1_{dd}] \quad \left[\begin{array}{c|c} B_{aa} & 0 \\ \hline 0 & 0 \end{array}\right] ,$$

$$[R_{dd}] \quad \left[\begin{array}{c|c} R_{aa} & 0 \\ \hline 0 & 0 \end{array}\right] ,$$

and

$$[K_{dd}] = [K^1_{dd}] + [K^2_{dd}] ,$$

$$[B_{dd}] = [B^1_{dd}] + [B^2_{dd}] .$$

(Nonzero values of the parameters W4, G, and W3 (see the PARAM bulk data card) are not recommended for use in heat transfer analysis and therefore do not appear in the above equations.)

78. Equivalence $[K^2_{dd}]$ to $[K_{dd}]$ and $[B^2_{dd}]$ to $[B_{dd}]$ if no matrices were generated from the element heat conduction and capacitance assemblers.

80. Beginning of loop for additional dynamic load sets.

81. CASE extracts the appropriate record from CASECC corresponding to the current loop and copies it into CASEXX.

82. TRLG generates matrices of heat flux loads versus time. $\{P^o_p\}$, $\{P^o_s\}$, and $\{P^o_d\}$ are generated with one column per output time step. $\{P^t_d\}$ is generated with one column per solution time step, and the Transient Output List is a list of output time steps.

83. Equivalence $\{P^o_p\}$ to $\{P^o_d\}$ if the d and p sets are the same.

84. TRHT integrates the equation of motion:

$$[B_{dd}] \{\dot{u}\} + [K_{dd}] \{u\} = \{P_d\} + \{N_d\} ,$$

where $\{u\}$ is a vector of temperatures at any time,

$\{\dot{u}\}$ is the time derivative of $\{u\}$ ("velocity"),

$\{P_d\}$ is the applied heat flux at any time step, and

$\{N_d\}$ is the total nonlinear heat flux from radiation and/or NØLINi data, extrapolated from the previous solution vector.

The output consists of the $[u^t_d]$ matrix containing temperature vectors and temperature "velocity" vectors for the output time steps.

85. VDR prepares the solution set temperatures, temperature "velocities", and nonlinear loads, sorted by time step, for output.

86. Go to DMAP No. 91 if there is no output request for the solution set.

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87. SDR3 prepares the requested output of the solution set temperatures, temperature "velocities", and nonlinear loads sorted by point number or element number.

88. ØFP formats the tables prepared by SDR3 for output sorted by point number or element number and places them on the system output file for printing.

89. XYTRAN prepares the input for requested X-Y plots of the solution set quantities.

90. XYPLØT prepares the requested X-Y plots of the solution set temperatures, "velocities" and nonlinear loads versus time.

93. Go to DMAP No. 109 if no further output is requested.

94. Equivalence $\{u_d\}$ to $\{u_p\}$ if no structure points were input.

95. Go to DMAP No. 97 if no structure points were input.

96. SDR1 recovers the dependent temperatures:

$$\{u_o\} = [G_o^d]\{u_d\} \quad ,$$

$$\left\{\frac{u_d}{u_o}\right\} = \{u_f\} \quad ,$$

$$\left\{\frac{u_f + u_e}{u_s}\right\} = \{u_n\} \quad ,$$

$$\{u_m\} = [G_m^d]\{u_f + u_e\}$$

and $$\left\{\frac{u_n + u_e}{u_m}\right\} = \{u_p\} \quad .$$

The module also recovers the heat flux into the points having single-point constraints:

$$\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\} \ .$$

98. SDR2 calculates requested heat flux transfer in the elements and prepares temperatures, "velocities", and heat flux loads for output sorted by time step.

99. SDRHT modifies the HØEF1 data block by combining the heat flow data from different sources for the HBDY elements and writes the results on the HØEF1X output data block.

100. Equivalence HØEF1 data block to the HØEF1X data block.

101. SDR3 prepares requested output sorted by point number or element number.

102. ØFP formats the tables prepared by SDR3 for output and places them on the system output file for printing.

103. Go to DMAP No. 106 if no temperature profile plots are requested.

104. PLØT generates all requested temperature profile plots and thermal contours for specified times.

105. PRTMSG prints plotter data, engineering data, and contour data for each temperature profile and thermal contour plot generated.

107. XYTRAN prepares the input for requested X-Y plots.

108. XYPLØT prepares the requested X-Y plots of temperatures, "velocities", element flux, and applied heat loads versus time.

110. Go to DMAP No. 116 if no additional dynamic load sets need to be processed.

111. Go to DMAP No. 80 if additional dynamic load sets need to be processed.

112. Print Error Message No. 2 and terminate execution.

113. Go to DMAP No. 116 and make normal exit.

115. Print Error Message No. 1 and terminate execution.

3.19.3 Output for Transient Heat Transfer Analysis

The following printed output, sorted by point number or element number (SØRT2), is available at selected multiples of the integration time step:

1. Temperatures (THERMAL) and derivatives of temperatures (VELØCITY) for a list of PHYSICAL points (grid points and extra scalar points introduced for dynamic analysis) or SDISPLACEMENT and SVELØCITY for SØLUTIØN points (points used in the formulation of the dynamic equation).
2. Nonzero components of the applied load vector (ØLØAD) and constrained heat flow (SPCFØRCE) for a list of PHYSICAL points.
3. Nonlinear load vector for a list of SØLUTIØN points.
4. Flux density (ELFØRCE) in selected elements.

The following plotter output is available:

1. Plot of the Structural model.
2. Temperature profiles and thermal contours for selected time intervals.
3. X-Y plot of temperature or derivative of temperature for a PHYSICAL point or a SØLUTIØN point.
4. X-Y plot of the applied load vector, nonlinear load vector, or constrained heat flow.
5. X-Y plot of flux density for an element.

The data used for preparing the X-Y plots may be punched or printed in tabular form (see Section 4.3). Also, a printed summary is prepared for each X-Y plot which includes the maximum and minimum values of the plotted function.

3.19.4 Case Control Deck for Transient Heat Transfer Analysis

The following items relate to subcase definition and data selection for Transient Heat Transfer Analysis:

1. One subcase must be defined for each dynamic loading condition.
2. DLØAD and/or NØNLINEAR must be used to define a time-dependent loading condition for each subcase. The static load cards (QVECT, QVØL, QHBDY, QBDY1, and QBDY2) can also be used to define a dynamic load by using these cards with, or instead of, the DAREA cards. The set identification number on the static load cards (field 2) is used in the same manner as the set identification number on the DAREA cards (field 2).
3. All constraints must be defined above the subcase level.

4. TSTEP must be used to select the time-step intervals to be used for integration and output in each subcase.

5. If nonzero initial conditions are desired, IC must be used to select a TEMP set in the Bulk Data Deck.

6. An estimated temperature distribution vector must be defined on TEMP cards and selected with a TEMP (MATERIAL) request if radiation effects are included.

7. On restart following an unscheduled exit due to insufficient time, the subcase structure should be changed to reflect any completed loading conditions.

3.19.5 Parameters for Transient Heat Transfer Analysis

The following parameters are used in Transient Heat Transfer Analysis:

1. TABS - optional. The real value of this parameter is the absolute reference temperature. The default value is 0.0.

2. SIGMA - optional. The real value of this parameter is the Stefan-Boltzmann constant. The default value is 0.0.

3. BETA - optional. The real value of this parameter is used as a factor in the integration algorithm (see Section 8.4.2 of the Theoretical Manual). The default value is 0.55.

4. RADLIN - optional. A positive integer value of this parameter causes some of the radiation efffects to be linearized (see Equation 2, Section 8.4.2 of the Theoretical Manual). The default value is -1.

5. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.

6. AUTØSPC - reserved for future optional use. The default value is -1.

3.19.6 Rigid Format Error Messages from Transient Heat Transfer Analysis

The following fatal errors are detected by the DMAP instructions in the Transient Heat Transfer Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional material, including suggestions for remedial action.

TRANSIENT HEAT TRANSFER ANALYSIS ERRØR MESSAGE NØ. 1 - TRANSIENT RESPØNSE LIST REQUIRED FØR TRANSIENT RESPØNSE CALCULATIØNS.

TRANSIENT HEAT TRANSFER ANALYSIS

Time step intervals to be used must be specified on a TSTEP card in the Bulk Data Deck and a TSTEP selection must be made in the Case Control Deck.

TRANSIENT HEAT TRANSFER ANALYSIS ERRØR MESSAGE NØ. 2 - ATTEMPT TØ EXECUTE MØRE THAN 100 LØØPS.

An attempt has been made to use more than 100 dynamic load sets. This number may be increased by ALTERing the REPT instruction following the last XYPLØT instruction.

3.20 MODAL FLUTTER ANALYSIS

3.20.1 DMAP Sequence for Modal Flutter Analysis

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OPTIONS IN EFFECT   GO     ERR=2   LIST    NODECK  NOREF   NOOSCAR

   1 BEGIN     AERO 10 - MODAL FLUTTER ANALYSIS - APR. 1984 $
   2 PRECHK    ALL $
   3 FILE      PHIHL=APPEND/AJJL=APPEND/FSAVE=APPEND/CASEYY=APPEND/CLAMAL=
               APPEND/ OVG=APPEND/QHHL=APPEND/SKJ=APPEND/QHJL=APPEND/QKHL=
               APPEND/ $
   4 PARAM     //*MPY*/CARDNO/0/0 $
   5 GP1       GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  S,N,
               NOGPDT/MINUS1=-1 $
   6 COND      ERROR5,NOGPDT $
   7 GP2       GEOM2,EQEXIN/ECT $
   8 PARAML    PCDB//*PRES*////JUMPPLOT $
   9 GP3       GEOM3,EQEXIN,GEOM2/,GPTT/NOGRAV $
  10 TA1       ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/LUSET/S,N,NOSIMP/1/
               S,N,NOGENL/S,N,GENEL $
  11 COND      ERROR5,NOSIMP $
  12 PARAM     //*ADD*/NOKGGX/1/0 $
  13 PARAM     //*ADD*/NOMGG /1/0 $
  14 EMG       EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,/S,N,NOKGGX/ S,
               N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/  C,Y,CPQUAD1/C,Y,
               CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/C,Y,CPTUBE/ C,Y,CPQDPLT/C,Y,
               CPTRPLT/C,Y,CPTRBSC $
  15 PURGE     KGGX,GPST/NOKGGX $
  16 COND      JMPKGGX,NOKGGX $
  17 EMA       GPECT,KDICT,KELM/KGGX,GPST $
  18 LABEL     JMPKGGX $
  19 COND      ERROR1,NOMGG $
  20 EMA       GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $
  21 COND      LGPWG,GRDPNT $
  22 GPWG      BGPDT,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $
  23 OFP       OGPWG,,,,,//S,N,CARDNO $
  24 LABEL     LGPWG $
  25 EQUIV     KGGX,KGG/NOGENL $
  26 COND      LBL11,NOGENL $
  27 SMA3      GEI,/KGGY/LUSET/NOGENL/-1 $
  28 ADD       KGGX,KGGY/KGG $
  29 LABEL     LBL11 $
```


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```
30  GP4      CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,USET,ASET/LUSET/
             S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/0/REPEAT/S,N,
             NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/S,Y,AUTOSPC $
31  PARAM    //*EQ*/GPSPFLG/AUTOSPC/0 $
32  COND     LBL4,GPSPFLG $
33  GPSP     GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
34  OFP      OGPST,,,,,//S,N,CARDNO $
35  LABEL    LBL4 $
36  EQUIV    KGG,KNN/MPCF1/MGG,MNN/MPCF1 $
37  PURGE    GM/MPCF1/DM,MR/REACT $
38  COND     LBL2,MPCF1 $
39  MCE1     USET,RG/GM $
40  MCE2     USET,GM,KGG,MGG,,/KNN,MNN,, $
41  LABEL    LBL2 $
42  EQUIV    KNN,KFF/SINGLE/MNN,MFF/SINGLE $
43  COND     LBL3,SINGLE $
44  SCE1     USET,KNN,MNN,,/KFF,KFS,,MFF,, $
45  LABEL    LBL3 $
46  EQUIV    KFF,KAA/OMIT/ MFF,MAA/OMIT $
47  PURGE    GO/OMIT $
48  COND     LBL5,OMIT $
49  PARAM    //*PREC*/PREC $
50  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
51  SMP2     USET,GO,MFF/MAA $
52  LABEL    LBL5 $
53  COND     LBL6,REACT $
54  RBMG1    USET,KAA,MAA/KLL,KLR,KRR,MLL,MLR,MRR $
55  RBMG2    KLL/LLL/ $
56  RBMG3    LLL,KLR,KRR/DM $
57  RBMG4    DM,MLL,MLR,MRR/MR $
58  LABEL    LBL6 $
59  DPD      DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPOOL,,,,,,EED,EQDYN/
             LUSET/S,N,LUSETD/NOTFL/NODLT/NOPSDL/NOFRL/  NONLFT/NOTRL/S,N,
             NOEED/123/S,N,NOUE $
60  COND     ERROR2,NOEED $
61  EQUIV    GO,GOD/NOUE/GM,GMD/NOUE $
62  READ     KAA,MAA,MR,DM,EED,USET,CASECC/LAMA,PHIA,MI,OEIGS/*MODES*/S,N,
             NEIGV $
63  OFP      OEIGS,,,,,//S,N,CARDNO $
64  COND     ERROR4,NEIGV $
```

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```
65  OFP       LAMA,,,,,//S,N,CARDNO $
66  MTRXIN    CASECC,MATPOOL,EQDYN,,TFPOOL/K2PP,M2PP,B2PP/LUSETD/S,N,
              NOK2PP/S,N,NOM2PP/S,N,NOB2PP $
67  EQUIV     M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA $
68  GKAD      USETD,GM,GO,,,,,K2PP,M2PP,B2PP/,,,GMD,GOD,K2DD,M2DD,B2DD/  *
              CMPLEV*/*DISP*/*MODAL*/0.0/0.0/0.0/NOK2PP/ NOM2PP/NOB2PP/MPCF1/
              SINGLE/OMIT/NOUE/   -1/-1/ -1/-1 $
69  GKAM      USETD,PHIA,,LAMA,DIT,M2DD,B2DD,K2DD,CASECC/MHH,BHH,KHH,PHIDH/
              NOUE/C,Y,LMODES=0/C,Y,LFREQ=0./C,Y,HFREQ=-1.0/NOM2PP/NOB2PP/
              NOK2PP/S,N,NONCUP/S,N,FMODE/C,Y,KDAMP $
70  APD       EDT,EQDYN,ECT,BGPDT,SILD,USETD,CSTM,GPLD/EQAERO,ECTA,BGPA,SILA,
              USETA,SPLINE,AERO,ACPT,FLIST,CSTMA,GPLA,SILGA/S,N,NK/S,N,NJ/S,
              N,LUSETA/S,N,BOV $
71  PARAM     //*MPY*/PFILE/0/1 $
72  PURGE     PLTSETA,PLTPARA,GPSETSA,ELSETSA//JUMPPLOT $
73  COND      SKPPLT,JUMPPLOT $
74  PARAM     //*MPY*/PLTFLG/0/1 $
75  PLTSET    PCDB,EQAERO,ECTA/PLTSETA,PLTPARA,GPSETSA,ELSETSA/S,N,NSIL1/S,N,
              JUMPPLOT $
76  PRTMSG    PLTSETA // $
77  COND      SKPPLT,JUMPPLOT $
78  PLOT      PLTPARA,GPSETSA,ELSETSA,CASECC,BGPA,EQAERO,,,,,/PLOTX2/
              NSIL1/LUSETA/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $
79  PRTMSG    PLOTX2 // $
80  LABEL     SKPPLT $
81  COND      ERROR2,NOEED $
82  GI        SPLINE,USET ,CSTMA,BGPA,SIL , ,GM,GO/GTKA/NK/LUSET $
83  PARAM     //*ADD*/DESTRY/0/1/ $
84  AMG       AERO,ACPT/AJJL,SKJ,D1JK,D2JK/NK/NJ/S,N,DESTRY $
85  COND      NODJE,NODJE $
86  INPUTT2   /D1JE,D2JE,,,/C,Y,P1=0/C,Y,P2=11/C,Y,P3=XXXXXXXX $
87  LABEL     NODJE $
88  PARAM     //*ADD*/XQHHL/1/0 $
89  AMP       AJJL,SKJ,D1JK,D2JK,GTKA,PHIDH,D1JE,D2JE,USETD,AERO/QHHL,QKHL,
              QHJL/NOUE/S,N,XQHHL/V,Y,GUSTAERO=-1 $
90  PARAM     //*MPY*/FLOOP/V,Y,NODJE=-1/0 $
91  LABEL     LOOPTOP $                                  Top of Flutter Loop
92  FA1       KHH,BHH,MHH,QHHL,CASECC,FLIST/FSAVE,KXHH,BXHH,MXHH/ S,N,FLOOP/
              S,N,TSTART/S,N,NOCEAD $
93  EQUIV     KXHH,PHIH/NOCEAD/BXHH,CLAMA/NOCEAD/KXHH,PHIHL/NOCEAD/BXHH,
              CLAMAL/NOCEAD/CASECC,CASEYY/NOCEAD $
94  COND      VDR,NOCEAD $
95  CEAD      KXHH,BXHH,MXHH,EED,CASECC/PHIH,CLAMA,OCEIGS,/S,N,EIGVS $
```

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```
 96  COND     LBLZAP,EIGVS $
 97  LABEL    VDR $
 98  VDR      CASECC,EQDYN ,USETD,PHIH,CLAMA,,/OPHIH,/*CEIGEN*/*MODAL*/
              123/S,N,NOH/S,N,NOP/FMODE $
 99  COND     LBL16,NOH $
100  OFP      OPHIH,,,,,//S,N,CARDNO $
101  LABEL    LBL16 $
102  FA2      PHIH,CLAMA,FSAVE/PHIHL,CLAMAL,CASEYY,OVG/S,N,TSTART/C,Y,VREF=
              1.0/C,Y,PRINT=YES $
103  COND     CONTINUE,TSTART $
104  LABEL    LBLZAP $
105  COND     CONTINUE,FLOOP $
106  REPT     LOOPTOP,100 $
                                               Bottom of Flutter Loop
107  JUMP     ERRORS $
108  LABEL    CONTINUE $
109  PARAML   XYCDB//*PRES*////NOXYCDB $
110  COND     NOXYOUT,NOXYCDB $
111  XYTRAN   XYCDB,OVG,,,,/XYPLTCE/*VG*/*PSET*/S,N,PFILE/S,N,CARDNO/  S,N,
              NOXYPL $
112  COND     NOXYOUT,NOXYPL $
113  XYPLOT   XYPLTCE// $
114  LABEL    NOXYOUT $
115  PARAM    //*AND*/PJUMP/NOP=-1/JUMPPLOT $
116  COND     FINIS,PJUMP $
117  MODACC   CASEYY,CLAMAL,PHIHL,,,/CLAMAL1,CPHIH1,CASEZZ,,/*CEIGN* $
118  ADR      CPHIH1,CASEZZ,QKHL,CLAMAL1,SPLINE,SILA,USETA/PKF/BOV/   C,Y,
              MACH = 0.0/*FLUTTER* $
119  DDR1     CPHIH1,PHIDH/CPHID $
120  EQUIV    CPHID ,CPHIP/NOA $
121  PURGE    QPC/NOA $
122  COND     LBL14,NOA $
123  SDR1     USETD,,CPHID ,,,GOD,GMD,,KFS,,/CPHIP,,QPC/1 /*DYNAMICS* $
124  LABEL    LBL14 $
125  EQUIV    CPHID ,CPHIA/NOUE $
126  COND     LBLNOE,NOUE $
127  VEC      USETA/RP/*D*/*A*/*E* $
128  PARTN    CPHID ,,RP/CPHIA,,,/1/3 $
129  LABEL    LBLNOE $
130  MPYAD    GTKA,CPHIA,/CPHIK/1/1/0/PREC $
```


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131  UMERGE   USETA,CPHIP,/CPHIPS/*PS*/*P*/*SA* $
132  UMERGE   USETA,CPHIPP,CPHIK/CPHIPA/*PA*/*PS*/*K* $
133  UMERGE   USETA,QPC,/QPAC/*PA*/*P*/*K* $
134  SDR2     CASEZZ,CSTMA,MPT,DIT,EQAERO,SILA,,,BGPA,CLAMAL1,QPAC,CPHIPA,
              EST,,/,OQPAC1,OCPHIPA,OESC1,OEFC1,PCPHIPA/*CEIGN* $
135  OFP      OCPHIPA,OQPAC1,OESC1,OEFC1,,//S,N,CARDNO $
136  COND     FINIS,JUMPPLOT $
137  PLOT     PLTPARA,GPSETSA,ELSETSA,CASEZZ,BGPA,EQAERO,SILGA,,PCPHIPA,,/
              PLOTX3/NSIL1/LUSETA/JUMPPLOT/PLTFLG/S,N,   PFILE $
138  PRTMSG   PLOTX3// $
139  JUMP     FINIS $
140  LABEL    ERROR3 $
141  PRTPARM  //-3/*FLUTTER* $
142  LABEL    ERROR2 $
143  PRTPARM  //-2/*FLUTTER* $
144  LABEL    ERROR1 $
145  PRTPARM  //-1/*FLUTTER* $
146  LABEL    ERROR4 $
147  PRTPARM  //-4/*FLUTTER* $
148  LABEL    ERROR5 $
149  PRTPARM  //-5/*FLUTTER* $
150  LABEL    FINIS $
151  PURGE    DUMMY/MINUS1 $
152  END      $
```

3.20.2 Description of DMAP Operations for Modal Flutter Analysis

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

6. Go to DMAP No. 148 and print Error Message No. 5 if no grid points are defined.

7. GP2 generates Element Connection Table with internal indices.

9. GP3 generates Static Loads Table and Grid Point Temperature Table.

10. TA1 generates element tables for use in matrix assembly and stress recovery.

11. Go to DMAP No. 148 and print Error Message No. 5 if no structural elements have been defined.

14. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

16. Go to DMAP No. 18 if no stiffness matrix is to be assembled.

17. EMA assembles stiffness matrix $[K^x_{gg}]$ and Grid Point Singularity Table.

19. Go to DMAP No. 144 and print Error Message No. 1 if no mass matrix is to be assembled.

20. EMA assembles mass matrix $[M_{gg}]$.

21. Go to DMAP No. 24 if no weight and balance information is requested.

22. GPWG generates weight and balance information.

23. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

25. Equivalence $[K^x_{gg}]$ to $[K_{gg}]$ if there are no general elements.

26. Go to DMAP No. 29 if there are no general elements.

27. SMA3 forms the general element stiffness matrix $[K^y_{gg}]$.

28. ADD combines the structural stiffness matrix $[K^x_{gg}]$ with the general element stiffness matrix $[K^y_{gg}]$ to obtain the stiffness matrix $[K_{gg}]$.

30. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations $[R_g]\{u_g\} = 0$.

32. Go to DMAP No. 35 if no potential grid point singularities exist.

33. GPSP generates a table of potential grid point singularities.

34. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

36. Equivalence $[K_{gg}]$ to $[K_{nn}]$ and $[M_{gg}]$ to $[M_{nn}]$ if no multipoint constraints exist.

38. Go to DMAP No. 41 if no multipoint constraints exist.

39. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

40. MCE2 partitions stiffness and mass matrices

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right] \quad \text{and} \quad [M_{gg}] = \left[\begin{array}{c|c} \bar{M}_{nn} & M_{nm} \\ \hline M_{mn} & M_{mm} \end{array}\right]$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \quad \text{and}$$

$$[M_{nn}] = [\bar{M}_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m] \ .$$

42. Equivalence $[K_{nn}]$ to $[K_{ff}]$ and $[M_{nn}]$ to $[M_{ff}]$ if no single-point constraints exist.

43. Go to DMAP No. 45 if no single-point constraints exist.

44. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right] \quad \text{and} \quad [M_{nn}] = \left[\begin{array}{c|c} M_{ff} & M_{fs} \\ \hline M_{sf} & M_{ss} \end{array}\right] \ .$$

46. Equivalence $[K_{ff}]$ to $[K_{aa}]$ and $[M_{ff}]$ to $[M_{aa}]$ if no omitted coordinates exist.

48. Go to DMAP No. 52 if no omitted coordinates exist.

50. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right] ,$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

51. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \left[\begin{array}{c|c} \bar{M}_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right]$$

and performs matrix reduction

$$[M_{aa}] = [\bar{M}_{aa}] + [M_{oa}^T][G_o] + [G_o^T][M_{oo}][G_o] + [G_o^T][M_{oa}] \ .$$

53. Go to DMAP No. 58 if there are no free-body supports.

54. RBMG1 partitions out free-body supports

$$[K_{aa}] = \left[\begin{array}{c|c} K_{\ell\ell} & K_{\ell r} \\ \hline K_{r\ell} & K_{rr} \end{array}\right] \quad \text{and} \quad [M_{aa}] = \left[\begin{array}{c|c} M_{\ell\ell} & M_{\ell r} \\ \hline M_{r\ell} & M_{rr} \end{array}\right]$$

55. RBMG2 decomposes constrained stiffness matrix $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$.

56. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}],$$

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D]$$

and calculates rigid body error ratio

$$\epsilon = \frac{||X||}{||K_{rr}||} .$$

57. RBMG4 forms rigid body mass matrix

$$[m_r] = [M_{rr}] + [M_{\ell r}^T][D] + [D^T][M_{\ell r}] + [D^T][M_{\ell\ell}][D].$$

59. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating the internal and external grid point numbers (GPLD), including extra points introduced for dynamic analysis (SILD), and prepares Transfer Function Pool (TFPØØL), and Eigenvalue Extraction Data (EED).

60. Go to DMAP No. 142 and print Error Message No. 2 if there is no Eigenvalue Extraction Data.

61. Equivalence $[G_o]$ to $[G_o^d]$ and $[G_m]$ to $[G_m^d]$ if there are no extra points introduced for dynamic analysis.

62. READ extracts real eigenvalues and eigenvectors from the equation

$$[K_{aa} - \lambda M_{aa}]\{\phi_a\} = 0 ,$$

calculates rigid body modes by finding a matrix $[\phi_{ro}]$ such that

$$[m_o] = [\phi_{ro}^T][m_r][\phi_{ro}]$$

is diagonal and normalized, computes rigid body eigenvectors

$$[\phi_{ao}] = \left[\begin{array}{c} D\phi_{ro} \\ \hline \phi_{ro} \end{array}\right] ,$$

calculates modal mass matrix

$$[m] = [\phi_a^T][M_{aa}][\phi_a]$$

and normalizes eigenvectors according to one of the following user requests:

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1) Unit value of a selected component
2) Unit value of the largest component
3) Unit value of the generalized mass.

63. ØFP formats the summary of eigenvalue extraction information (ØEIGS) prepared by READ and places it on the system output file for printing.

64. Go to DMAP No. 146 and print Error Message No. 4 if no eigenvalues were found.

65. ØFP formats the eigenvalues (LAMA) prepared by READ and places them on the system output file for printing.

66. MXTRIN selects the direct input matrices $[K^2_{pp}]$, $[M^2_{pp}]$ and $[B^2_{pp}]$.

67. Equivalence $[M^2_{pp}]$ to $[M^2_{dd}]$, $[B^2_{pp}]$ to $[B^2_{dd}]$ and $[K^2_{pp}]$ to $[K^2_{dd}]$ if no constraints are applied.

68. GKAD applies constraints to direct input matrices $[K^2_{pp}]$, $[M^2_{pp}]$ and $[B^2_{pp}]$, forming $[K^2_{dd}]$, $[M^2_{dd}]$ and $[B^2_{dd}]$ and forms $[G_{md}]$ and $\lfloor G_{od}\rfloor$.

69. GKAD selects eigenvectors to form $[\phi_{dh}]$ and assembles stiffness, mass and damping matrices in modal coordinates:

$$[K_{hh}] = \left[\begin{array}{c|c} k_i & 0 \\ \hline 0 & 0 \end{array}\right] + [\phi^T_{dh}][K^2_{dd}][\phi_{dh}] \ ,$$

$$[M_{hh}] = \left[\begin{array}{c|c} m_i & 0 \\ \hline 0 & 0 \end{array}\right] + [\phi^T_{dh}][M^2_{dd}][\phi_{dh}] \ ,$$

$$[B_{hh}] = \left[\begin{array}{c|c} b_i & 0 \\ \hline 0 & 0 \end{array}\right] + [\phi^T_{dh}][B^2_{dd}][\phi_{dh}] \ ,$$

where

<u>KDAMP = -1 (default)</u>	<u>KDAMP = 1</u>
m_i = modal masses	m_i = modal masses
$b_i = m_i\ 2\pi\ f_i\ g(f_i)$	$b_i = 0$
$k_i = m_i\ 4\pi^2\ f_i$	$k_i = (1+ig(f_i))\ 4\pi^2\ f_i^2 m_i$

70. APD processes the aerodynamic data cards from EDT. It adds the k points and the SA points to USETD making USETA. EQAERØ, ECTA, BGPA, CSTMA, GPLA and SILA are updated to reflect the new elements. AERØ and ACPT reflect the aerodynamic parameters. SILGA is a special SIL for plotting.

73. Go to DMAP No. 80 if no plot output is requested.

75. PLTSET transforms user input into a form used to drive the structure plotter.

76. PRTMSG prints error messages associated with the structure plotter.

77. Go to DMAP No. 80 if no undeformed aerodynamic or structural element plots are requested.

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78. PLØT generates all requested undeformed aerodynamic and structural element plots.

79. PRTMSG prints plotter data and engineering data for each undeformed aerodynamic and structural element plot generated.

81. Go to DMAP No. 142 and print Error Message No. 2 if there is no Eigenvalue Extraction Data.

82. GI forms a transformation matrix $[G_{ka}^T]$ which interpolates between aerodynamic (k) and structural (a) degrees of freedom.

84. AMG forms the aerodynamic matrix list $[A_{jj}]$, the area matrix $[S_{kj}]$, and the downwash coefficients $[D_{jk}^1]$ and $[D_{jk}^2]$.

85. Go to DMAP No. 87 if there are no user-supplied downwash coefficients.

86. INPUTT2 provides the user-supplied downwash factors due to extra points ($[D_{je}^1]$, $[D_{je}^2]$). PARAM NØDJE must be set to enter these matrices. The downwash w_j on box j due to the motion of an extra point, u_e, is given by

$$\{w_j\} = [D_{je}^1 + ikD_{je}^2]\{u_e\} .$$

89. AMP computes the aerodynamic matrix list related to the modal coordinates as follows:

$$[\phi_{dh}] = \left[\begin{array}{c|c} \phi_{ai} & \phi_{ae} \\ \hline \phi_{ei} & \phi_{ee} \end{array}\right] , \qquad [G_{ki}] = [G_{ka}^T]^T[\phi_{ai}] ,$$

$$[D_{jh}^1] \Leftarrow [D_{ji}^1 \mid D_{je}^1] , \qquad [D_{ji}^1] = [D_{jk}^1]^T[G_{ki}] ,$$

$$[D_{jh}^2] \Leftarrow [D_{ji}^2 \mid D_{je}^2] \text{ and } \qquad [D_{ji}^2] = [D_{jk}^2]^T[G_{ki}].$$

For each (m,k) pair:

$$[D_{jh}] = [D_{jh}^1] + ik[D_{jh}^2] .$$

For each group:

$$[Q_{jh}] = [A_{jj}^T]^{-1}_{group} [D_{jh}]_{group} ,$$

$$[Q_{kh}] = [S_{kj}][Q_{jh}] ,$$

$$[Q_{ih}] = [G_{ki}]^T[Q_{kh}]$$

and

$$[Q_{hh}] \Leftarrow \left[\begin{array}{c} Q_{ih} \\ \hline Q_{eh} \end{array}\right] .$$

90. PARAM initializes the flutter loop counter (FLØØP) to zero.

91. Beginning of loop for flutter.

92. FA1 computes the total aerodynamic mass matrix $[M_{hh}^x]$, the total aerodynamic stiffness matrix $[K_{hh}^x]$ and the total aerodynamic damping matrix $[B_{hh}^x]$ as well as a looping table

FSAVE. For the K-method

$$M^x_{hh} = (k^2/b^2)M_{hh} + (p/2)\,Q_{hh} \;,$$

$$K^x_{hh} = K_{hh}$$

and $$B^x_{hh} = 0 \;.$$

93. Set up equivalences for the KE- and PK-methods.

94. Go to DMAP No. 97 for the KE- and PK-methods.

95. CEAD extracts complex eigenvalues and eigenvectors from the equation

$$[M^x_{hh}p^2 + B^x_{hh}p + K^x_{hh}]\{\phi_h\} = 0$$

and normalizes eigenvectors to unit magnitude of the largest component.

96. Go to DMAP No. 104 if no complex eigenvalues were found.

98. VDR prepares eigenvectors (ØPHIH) for output, using only the extra points introduced for dynamic analysis and modal coordinates.

99. Go to DMAP No. 101 if there is no output request for the extra points introduced for dynamic analysis or modal coordinates.

100. ØFP formats the table of eigenvectors for extra points introduced for dynamic analysis and modal coordinates prepared by VDR and places it on the system output file for printing.

102. FA2 appends eigenvectors to PHIHL, eigenvalues to CLAMAL, Case Control to CASEYY, and V-g plot data to ØVG.

103. Go to DMAP No. 108 if there is insufficient time for another flutter loop.

105. Go to DMAP No. 108 if the flutter loop is complete.

106. Go to DMAP No. 91 for additional aerodynamic configuration triplet values.

107. Go to DMAP No. 140 and print Error Message No. 3 if the number of flutter loops exceeds 100.

110. Go to DMAP No. 114 if there are no X-Y plot requests.

111. XYTRAN prepares the input for requested V-g plotting.

112. Go to DMAP No. 114 if no plots are possible as requested.

113. XYPLØT prepares the requested V-g plots.

116. Go to DMAP No. 150 and make normal exit if there are no output requests involving dependent degrees of freedom or forces and stresses.

117. MØDACC selects a list of eigenvalues and eigenvectors whose imaginary parts (velocity in input units) are close to a user input list.

118. ADR builds a matrix of aerodynamic forces for each aerodynamic point and prints requested aerodynamic forces for selected elements.

119. DDR1 transforms the complex eigenvectors from modal to physical coordinates

$$\{\phi_d^c\} = \{\phi_{dh}\}\{\phi_h\} .$$

120. Equivalence $\{\phi_d^c\}$ to $\{\phi_p^c\}$ if no constraints are applied.

122. Go to DMAP No. 124 if no constraints are applied.

123. SDR1 recovers dependent components of eigenvectors

$$\{\phi_o^c\} = [G_o^d]\{\phi_d^c\} \quad , \qquad \left\{\begin{array}{c}\phi_d \\ \hline \phi_o\end{array}\right\} = \{\phi_f^c + \phi_e^c\} \quad ,$$

$$\left\{\begin{array}{c}\phi_f^c + \phi_e^c \\ \hline \phi_s^c\end{array}\right\} = \{\phi_n^c + \phi_e^c\} \quad , \qquad \{\phi_m^c\} = [G_m^d]\{\phi_n^c + \phi_e^c\} \quad ,$$

$$\left\{\begin{array}{c}\phi_f^c + \phi_e^c \\ \hline \phi_m^c\end{array}\right\} = \{\phi_p^c\}$$

and recovers single-point forces of constraint $\{q_s\} = [K_{fs}^T]\{\phi_f\}$, $\left\{\begin{array}{c}0 \\ \hline q_s\end{array}\right\} = \{Q_p\}$.

125. Equivalence $\{\phi_d^c\}$ to $\{\phi_a^c\}$ if there are no extra points introduced for dynamic analysis.

126. Go to DMAP No. 129 if there are no extra points.

127. VEC generates a d-size partitioning vector (RP) for the a- and e-sets

$$\{u_d\} \rightarrow \{u_a\} + \{u_e\} .$$

128. PARTN performs partition of $\{\phi_d^c\}$ using RP

$$\{\phi_d^c\} \Rightarrow \left\{\begin{array}{c}\phi_a^c \\ \hline \phi_e^c\end{array}\right\} .$$

130. MPYAD recovers the displacements at the aerodynamic points (k)

$$\{\phi_k^c\} = [G_{ka}^T]^T\{\phi_a^c\} .$$

131. UMERGE is used to expand $\{\phi_p^c\}$ to the ps-set.

132. UMERGE places $\{\phi_k^c\}$ in its proper place in the displacement vector

$$\{\phi_{pa}^c\} \Leftarrow \left\{\begin{array}{c}\phi_{ps}^c \\ \hline \phi_k^c\end{array}\right\} .$$

133. UMERGE is used to expand $\{Q_p^c\}$ to the pa-set.

134. SDR2 calculates element forces (ØEFC1) and stresses (ØESC1) and prepares eigenvectors (ØCPHIPA) and single-point forces of constraint (ØQPAC1) for output and PCPHIPA for deformed plotting.

135. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

136. Go to DMAP No. 150 and make normal exit if no deformed aerodynamic or structural element plots are requested.

137. PLØT prepares all deformed aerodynamic and structural element plots.

138. PRTMSG prints plotter data and engineering data for each deformed plot generated.

139. Go to DMAP No. 150 and make normal exit.

141. Print Error Message No. 3 and terminate execution.

143. Print Error Message No. 2 and terminate execution.

145. Print Error Message No. 1 and terminate execution.

147. Print Error Message No. 4 and terminate execution.

149. Print Error Message No. 5 and terminate execution.

3.20.3 Output for Modal Flutter Analysis

The real Eigenvalue Summary Table and the real Eigenvalue Analysis Summary, as described under Normal Mode Analysis (see Section 3.4.3), are automatically printed. All real eigenvalues are included even though all may not be used in the modal formulation.

The complex eigenvalues are included in the Flutter Summary and are printed for each aerodynamic loop.

The grid point singularities from the structural model are also output.

A Flutter Summary for each value of the configuration parameters is printed out unless PRINT=NØ. This shows Mach number, density, reduced frequency, velocity, damping, and frequency for each complex eigenvalue.

V-g and V-f plots may be requested by the XYØUT control cards by specifying the curve type as VG. The "points" are loop numbers and the "components" are G or F.

Printed output of the following types, sorted by complex eigenvalue root number (SØRT1) and (m, k, ρ), may be requested for all complex eigenvalues kept, either as real and imaginary parts or as magnitude and phase angle (0° - 360° lead). (Eigenvectors are not available for the KE-method).

1. The eigenvector for a list of PHYSICAL and AERØDYNAMIC points (grid points, extra points, and aerodynamic points) or SØLUTIØN points (modal coordinates and extra points).
2. Nonzero components of the single-point forces of constraint for a list of PHYSICAL points.
3. Complex stresses and forces in selected elements.

The ØFREQUENCY Case Control card can select a subset of the complex eigenvectors for data recovery. In addition, undeformed and deformed shapes may be requested. Undeformed shapes may include only structural or structural and aerodynamic elements.

The eigenvectors used in the modal formulation may be obtained for the analysis points by using the ALTER feature to print the matrix of eigenvectors following the execution of READ. The eigenvectors for all points in the model may be obtained by running the problem initially on the Normal Mode Analysis Rigid Format or by making a modified restart using the Normal Mode Analysis Rigid Format.

3.20.4 Case Control Deck for Modal Flutter Analysis

The following items relate to subcase definition and data selection for Modal Flutter Analysis:

1. Only one subcase is allowed.
2. Desired direct input matrices for stiffness $[K^2_{pp}]$, mass $[M^2_{pp}]$, and damping $[B^2_{pp}]$ must be selected via the keywords K2PP, M2PP, or B2PP.
3. CMETHØD must be used to select an EIGC card from the Bulk Data Deck. (K method only).
4. FMETHØD must be used to select a FLUTTER card from the Bulk Data Deck.
5. METHØD must be used to select an EIGR card that exists in the Bulk Data Deck.
6. SDAMPING must be used to select a TABDMP1 table if structural damping is desired.

3.20.5 Parameters for Modal Flutter Analysis

The following parameters are used in Modal Flutter Analysis:

1. GRDPNT - optional. A positive integer value of this parameter will cause the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
2. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in EMA. Not recommended for use in hydroelastic problems.
3. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters will cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. LFREQ and HFREQ - required unless LMØDES is used. The real values of these parameters give the frequency range (LFREQ is the lower limit and HFREQ is the upper limit) of the modes to be used in the modal formulation.
5. LMØDES - required unless LFREQ and HFREQ are used. The integer value of this parameter is the number of lowest modes to be used in the modal formulation.
6. NØDJE - optional. A positive integer of this parameter indicates that user supplied downwash matrices due to extra points are to be read in via the INPUTT2 module in the rigid format. The default value is -1 when not needed.

7. P1, P2 and P3 - required when using the NØDJE parameter. See Section 5.5 for a description of these parameters which are required by the INPUTT2 module. The defaults for P1, P2 and P3 are 0, 11 and XXXXXXXX, respectively.
8. VREF - optional. Velocities are divided by the real value of this parameter to convert units or to compute flutter indices. The default value is 1.0.
9. PRINT - optional. The BCD value, NØ, of this parameter will suppress the automatic printing of the flutter summary for the K method. The default value is YES.
10. GUSTAERØ - optional. If gust loads are to be computed (on restart for instance), set value to +1. The default is -1 for no gust loads.
11. KDAMP - optional. If set to +1, modal damping is put into a complex stiffness matrix as structural damping (+1 recommended for K and KE methods). The default value is -1.
12. MACH - optional. The real value of this parameter selects the closest Mach numbers to be used to compute aerodynamic matrices. The default is 0.0.
13. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
14. AUTØSPC - reserved for future optional use. The default value is -1.

3.20.6 Optional Diagnostic Output for FEER

Special detailed information obtained by requesting DIAG 16 in the Executive Control Deck is the same as that described under Normal Mode Analysis (see Section 3.4.6).

3.20.7 The APPEND Feature

The APPEND feature can be used for real eigenvalue extraction in Modal Flutter Analysis. See Section 3.4.7 for details.

3.20.8 Rigid Format Error Messages from Modal Flutter Analysis

The following fatal errors are detected by the DMAP statements in the Modal Flutter Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

MØDAL FLUTTER ANALYSIS ERRØR MESSAGE NØ. 1 - MASS MATRIX REQUIRED FØR MØDAL FØRMULATION.

The mass matrix is null because either no structural elements were defined with Connection cards, nonstructural mass was not defined on a Property card or the density was not defined on a Material card.

MØDAL FLUTTER ANALYSIS ERRØR MESSAGE NØ. 2 - EIGENVALUE EXTRACTIØN DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGR card in the Bulk Data Deck and METHØD in the Case Control Deck must select an EIGR set.

MØDAL FLUTTER ANALYSIS ERRØR MESSAGE NØ. 3 - ATTEMPT TØ EXECUTE MØRE THAN 100 LØØPS.

An attempt has been made to use more than 100 flutter loops. This number can be increased by ALTERing the REPT instruction following FA2.

MØDAL FLUTTER ANALYSIS ERRØR MESSAGE NØ. 4 - REAL EIGENVALUES REQUIRED FØR MØDAL FØRMULATIØN.

No real eigenvalues were found in the frequency range specified by the user.

MØDAL FLUTTER ANALYSIS ERRØR MESSAGE NØ. 5 - NØ GRID PØINT DATA IS SPECIFIED ØR NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No points have been defined with GRID or SPØINT cards or no structural elements have been defined with Connection cards.

3.21 MODAL AEROELASTIC RESPONSE

3.21.1 DMAP Sequence for Modal Aeroelastic Response

```
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OPTIONS IN EFFECT   GO     ERR=2   LIST    NODECK  NOREF    NOOSCAR

  1  BEGIN    AERO 11 - MODAL AEROELASTIC RESPONSE - APR. 1984 $
  2  PRECHK   ALL $
  3  FILE     AJJL=APPEND/QHHL=APPEND/QKHL=APPEND/QHJL=APPEND/SKJ=APPEND $
  4  PARAM    //*MPY*/CARDNO/0/0 $
  5  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  S,N,
              NOGPDT/MINUS1=-1 $
  6  COND     ERROR3,NOGPDT $
  7  GP2      GEOM2,EQEXIN/ECT $
  8  PARAML   PCDB//*PRES*/V,Y,NODJE=-1///JUMPPLOT $
  9  PARAML   XYCDB//*PRES*////NOXYCDB $
 10  GP3      GEOM3,EQEXIN,GEOM2/,GPTT/NOGRAV $
 11  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/LUSET/S,N,NOSIMP/1/
              S,N,NOGENL/S,N,GENEL $
 12  COND     ERROR3,NOSIMP $
 13  PARAM    //*ADD*/NOKGGX/1/0 $
 14  PARAM    //*ADD*/NOMGG /1/0 $
 15  EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,/S,N,NOKGGX/ S,
              N,NOMGG////C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/  C,Y,CPQUAD1/C,Y,
              CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/C,Y,CPTUBE/ C,Y,CPQDPLT/C,Y,
              CPTRPLT/C,Y,CPTRBSC $
 16  PURGE    KGGX,GPST/NOKGGX $
 17  COND     JMPKGGX,NOKGGX $
 18  EMA      GPECT,KDICT,KELM/KGGX,GPST $
 19  LABEL    JMPKGGX $
 20  COND     ERROR1,NOMGG $
 21  EMA      GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $
 22  COND     LGPWG,GRDPNT $
 23  GPWG     BGPDT,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $
 24  OFP      OGPWG,,,,,//S,N,CARDNO $
 25  LABEL    LGPWG $
 26  EQUIV    KGGX,KGG/NOGENL $
 27  COND     LBL11,NOGENL $
 28  SMA3     GEI,/KGGY/LUSET/NOGENL/-1 $
 29  ADD      KGGX,KGGY/KGG $
 30  LABEL    LBL11 $
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```
31  GP4      CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,USET,ASET/LUSET/
             S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/0/S,N,REPEAT/
             S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/S,Y,AUTOSPC $

32  PARAM    //*EQ*/GPSPFLG/AUTOSPC/0 $

33  PURGE    GM/MPCF1/DM,MR/REACT $

34  COND     LBL4,GPSPFLG $

35  GPSP     GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $

36  OFP      OGPST,,,,,//S,N,CARDNO $

37  LABEL    LBL4 $

38  EQUIV    KGG,KNN/MPCF1/MGG,MNN/MPCF1 $

39  COND     LBL2,MPCF1 $

40  MCE1     USET,RG/GM $

41  MCE2     USET,GM,KGG,MGG,,/KNN,MNN,, $

42  LABEL    LBL2 $

43  EQUIV    KNN,KFF/SINGLE/MNN,MFF/SINGLE $

44  COND     LBL3,SINGLE $

45  SCE1     USET,KNN,MNN,,/KFF,KFS,,MFF,, $

46  LABEL    LBL3 $

47  EQUIV    KFF,KAA/OMIT/ MFF,MAA/OMIT $

48  PURGE    GO/OMIT $

49  COND     LBL5,OMIT $

50  PARAM    //*PREC*/PREC $

51  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $

52  SMP2     USET,GO,MFF/MAA $

53  LABEL    LBL5 $

54  COND     LBL6,REACT $

55  RBMG1    USET,KAA,MAA/KLL,KLR,KRR,MLL,MLR,MRR $

56  RBMG2    KLL/LLL/ $

57  RBMG3    LLL,KLR,KRR/DM $

58  RBMG4    DM,MLL,MLR,MRR/MR $

59  LABEL    LBL6 $

60  DPD      DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPOOL,DLT,PSDL,FRL,,TRL,
             EED,EQDYN/LUSET/S,N,LUSETD/NOTFL/NODLT/S,N,NOPSDL/  NOFRL/
             NONLFT/NOTRL/S,N,NOEED/123/S,N,NOUE $

61  COND     ERROR2,NOEED $

62  EQUIV    GO,GOD/NOUE/GM,GMD/NOUE $

63  READ     KAA,MAA,MR,DM,EED,USET,CASECC/LAMA,PHIA,MI,OEIGS/*MODES*/S,N,
             NEIGV $

64  OFP      OEIGS,,,,,//S,N,CARDNO $
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```
65  COND     ERROR4,NEIGV $
66  OFP      LAMA,,,,,//S,N,CARDNO $
67  MTRXIN   CASECC,MATPOOL,EQDYN,,TFPOOL/K2PP,M2PP,B2PP/LUSETD/S,N,
             NOK2PP/S,N,NOM2PP/S,N,NOB2PP $
68  EQUIV    M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA $
69  GKAD     USETD,GM,GO,,,,,K2PP,M2PP,B2PP/,,,GMD,GOD,K2DD,M2DD,B2DD/  *
             CMPLEV*/*DISP*/*MODAL*/0.0/0.0/0.0/NOK2PP/ NOM2PP/NOB2PP/MPCF1/
             SINGLE/OMIT/NOUE/    -1/-1/-1/-1 $
70  GKAM     USETD,PHIA,,LAMA,DIT,M2DD,B2DD,K2DD,CASECC/MHH,BHH,KHH,PHIDH/
             NOUE/C,Y,LMODES=0/C,Y,LFREQ=0./C,Y,HFREQ=-1.0/NOM2PP/NOB2PP/
             NOK2PP/S,N,NONCUP/S,N,FMODE/C,Y,KDAMP $
71  APD      EDT,EQDYN,ECT,BGPDT,SILD,USETD,CSTM,GPLD/EQAERO,ECTA,BGPA,SILA,
             USETA,SPLINE,AERO,ACPT,FLIST,CSTMA,GPLA,SILGA/S,N,NK/S,N,NJ/S,
             N,LUSETA/S,N,BOV $
72  PARAM    //*MPY*/PFILE/0/1 $
73  PURGE    PLTSETA,PLTPARA,GPSETSA,ELSETSA/JUMPPLOT $
74  COND     SKPPLT,JUMPPLOT $
75  PARAM    //*MPY*/PLTFLG/0/1 $
76  PLTSET   PCDB,EQAERO,ECTA/PLTSETA,PLTPARA,GPSETSA,ELSETSA/S,N,NSIL1/S,N,
             JUMPPLOT $
77  PRTMSG   PLTSETA // $
78  COND     SKPPLT,JUMPPLOT $
79  PLOT     PLTPARA,GPSETSA,ELSETSA,CASECC,BGPA,EQAERO, ,,,,/PLOTX2/
             NSIL1/LUSETA/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $
80  PRTMSG   PLOTX2 // $
81  LABEL    SKPPLT $
82  GI       SPLINE,USET ,CSTMA,BGPA,SIL , ,GM,GO/GTKA/NK/LUSET $
83  PARAM    //*ADD*/DESTRY/0/1/ $
84  AMG      AERO,ACPT/AJJL,SKJ,D1JK,D2JK/NK/NJ/S,N,DESTRY $
85  COND     NODJE,NODJE $
86  INPUTT2  /D1JE,D2JE,,,/C,Y,P1=0/C,Y,P2=11/C,Y,P3=XXXXXXXX $
87  LABEL    NODJE $
88  PARAM    //*ADD*/XQHHL/1/0 $
89  AMP      AJJL,SKJ,D1JK,D2JK,GTKA,PHIDH,D1JE,D2JE,USETD,AERO/QHHL,QKHL,
             QHJL/NOUE/S,N,XQHHL/V,Y,GUSTAERO=-1 $
90  FRLG     CASECC,USETD,DLT,FRL,GMD,GOD,DIT,PHIDH/PPF,PSF,PDF,FOL,PHF1/
             *MODAL*/S,N,FREQY/S,N,APP $
91  PARAM    //*NOT*/NOFRY/FREQY $
92  PURGE    PPF/NOFRY $
93  GUST     CASECC,DLT,FRL,DIT,QHJL,,,ACPT,CSTMA,PHF1/PHF/ S,N,NOGUST/BOV/
             C,Y,MACH/C,Y,Q $
94  EQUIV    PHF1,PHF/NOGUST $
95  FRRD2    KHH,BHH,MHH,QHHL,PHF,FOL/UHVF/BOV/C,Y,Q/C,Y,MACH $
```


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```
 96  EQUIV   UHVF,UHVT/FREQY/FOL,TOL/FREQY $
 97  COND    IFTSKP,FREQY $
 98  IFT     UHVF,CASECC,TRL,FOL/UHVT,TOL/C,Y,IFTM=0 $
 99  LABEL   IFTSKP $
100  MODACC  CASECC,TOL,UHVT,,,/TOL1,UHVT1,,,/APP $
101  ADR     UHVT1,CASECC,QKHL,TOL1,SPLINE,SILA,USETA/PKF/BOV/   C,Y,MACH/
             APP $
102  VDR     CASECC,EQDYN,USETD,UHVT1,TOL1,XYCDB,/OUHV1,/APP/*MODAL*/0/S,N,
             NOH/S,N,NOP/FMODE $
103  COND    NOH,NOH $
104  SDR3    OUHV1,,,,,/OUHV2,,,,, $
105  OFP     OUHV2,,,,,//S,N,CARDNO $
106  COND    NOH,NOXYCDB $
107  XYTRAN  XYCDB,OUHV2,,,,/XYPTTA/APP/*HSET*/S,N,PFILE/S,N,CARDNO/   S,N,
             NOXYPL $
108  COND    NOH,NOXYPL $
109  XYPLOT  XYPTTA $
110  LABEL   NOH $
111  PARAM   //*AND*/PJUMP/NOP/JUMPPLOT $
112  COND    FINIS,PJUMP $
113  SDR1    USETD,,PHIDH,,,GOD,GMD,,KFS,,/PHIP,,QP/1/*DYNAMICS* $
114  EQUIV   PHIDH,PHIAH/NOUE $
115  COND    NOUE1,NOUE $
116  VEC     USETD/EVEC/*D*/*A*/*E* $
117  PARTN   PHIDH,,EVEC/PHIAH,,,/1 $
118  LABEL   NOUE1 $
119  MPYAD   GTKA,PHIAH,/PHIK/1/1/0/PREC $
120  UMERGE  USETA,PHIP,/PHIPS/*PS*/*P*/*SA* $
121  UMERGE  USETA,PHIPS,PHIK/PHIPA/*PA*/*PS*/*K* $
122  UMERGE  USETA,QP,/QPA/*PA*/*P*/*PS* $
123  SDR2    CASECC,CSTMA,MPT,DIT,EQAERO,SILA,,,BGPA,LAMA,QPA,PHIPA,EST,
             XYCDB,/ ,MQP1,MPHIPA1,MES1,MEF1,/*MMREIG* $
124  COND    NOPF,NOFRY $
125  SDR2    CASECC,,,,EQDYN,,,,,PPF,,,,XYCDB,/OPP1,,,,,/*FREQ* $
126  SDR3    OPP1,,,,,/OPP2,,,,,/ $
127  LABEL   NOPF $
128  SDR3    MPHIPA1,MES1,MEF1,MQP1,,/MPHIPA2,MES2,MEF2,MQP2,, $
129  DDRMM   CASECC,UHVT1,TOL1,MPHIPA2,MQP2,MES2,MEF2,XYCDB,EST,MPT,DIT/
             OUPV2,OQP2,OES2,OEF2, $
130  OFP     OUPV2,,OES2,OEF2,OQP2,//S,N,CARDNO $
```

RIGID FORMAT DMAP LISTING
RELEASE APR. 1984

AERO APPROACH, RIGID FORMAT 11

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
131  COND      P2,JUMPPLOT $
132  MPYAD     PHIPA,UHVT1,/UVT1/0 $
133  SDR2      CASECC,CSTMA,,,EQAERO,,,,BGPA,TOL,,UVT1,,,/,,,,,PUVPAT/APP $
134  PLOT      PLTPARA,GPSETSA,ELSETSA,CASECC,BGPA,EQAERO,SILGA,,PUVPAT,,/
               PLOTX3/NSIL1/LUSETA/JUMPPLOT/PLTFLG/PFILE $
135  PRTMSG    PLOTX3// $
136  LABEL     P2 $
137  COND      FINIS,NOXYCDB $
138  XYTRAN    XYCDB,,OQP2,OUPV2,OES2,OEF2/XYPLTT/APP/*PSET*/   S,N,PFILE/S,N,
               CARDNO/S,N,NOXYPL $
139  COND      NOXYPLTT,NOXYPL $
140  XYPLOT    XYPLTT $
141  LABEL     NOXYPLTT $
142  COND      FINIS,NOFRY $
143  COND      FINIS,NOPSDL $
144  RANDOM    XYCDB,DIT,PSDL,OUPV2,,OQP2,OES2,OEF2,CASECC/PSDF,AUTO/   S,N,
               NORN $
145  COND      FINIS,NORN $
146  XYTRAN    XYCDB,PSDF,AUTO,,,/XYPLTR/*RAND*/*PSET*/S,N,PFILE/   S,N,
               CARDNO/S,N,NOXYPL $
147  COND      FINIS,NOXYPL $
148  XYPLOT    XYPLTR $
149  JUMP      FINIS $
150  LABEL     ERROR2 $
151  PRTPARM   //-2/*AERORESP* $
152  LABEL     ERROR1 $
153  PRTPARM   //-1/*AERORESP* $
154  LABEL     ERROR4 $
155  PRTPARM   //-4/*AERORESP* $
156  LABEL     ERROR3 $
157  PRTPARM   //-3/*AERORESP* $
158  LABEL     FINIS $
159  PURGE     DUMMY/MINUS1 $
160  END       $
```

3.21.2 Description of DMAP Operations for Modal Aeroelastic Response

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.

6. Go to DMAP No. 156 and print Error Message No. 3 if no grid points are defined.

7. GP2 generates Element Connection Table with internal indices.

10. GP3 generates Grid Point Temperature Table (element temperature).

11. TA1 generates element tables for use in matrix assembly and stress recovery.

12. Go to DMAP No. 156 and print Error Message No. 3 if no structural elements have been defined.

15. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.

17. Go to DMAP No. 19 if no stiffness matrix is to be assembled.

18. EMA assembles stiffness matrix $[K^x_{gg}]$ and Grid Point Singularity Table.

20. Go to DMAP No. 152 and print Error Message No. 1 if no mass matrix is to be assembled.

21. EMA assembles mass matrix $[M_{gg}]$.

22. Go to DMAP No. 25 if no weight and balance information is requested.

23. GPWG generates weight and balance information.

24. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.

26. Equivalence $[K^x_{gg}]$ to $[K_{gg}]$ if there are no general elements.

27. Go to DMAP No. 30 if there are no general elements.

28. SMA3 forms the general element stiffness matrix $[K^y_{gg}]$.

29. ADD combines the structural stiffness matrix $[K^x_{gg}]$ with the general element stiffness matrix $[K^y_{gg}]$ to obtain the stiffness matrix $[K_{gg}]$.

31. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations $[R_g]\{u_g\} = 0$.

34. Go to DMAP No. 37 if no potential grid point singularities exist.

35. GPSP generates a table of potential grid point singularities.

36. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

38. Equivalence $[K_{gg}]$ to $[K_{nn}]$ and $[M_{gg}]$ to $[M_{nn}]$ if no multipoint constraints exist.

39. Go to DMAP No. 42 if no multipoint constraints exist.

40. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

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41. MCE2 partitions stiffness and mass matrices

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right] \quad \text{and} \quad [M_{gg}] = \left[\begin{array}{c|c} \bar{M}_{nn} & M_{nm} \\ \hline M_{mn} & M_{mm} \end{array}\right]$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \quad \text{and}$$

$$[M_{nn}] = [\bar{M}_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m] \ .$$

43. Equivalence $[K_{nn}]$ to $[K_{ff}]$ and $[M_{nn}]$ to $[M_{ff}]$ if no single-point constraints exist.

44. Go to DMAP No. 46 if no single-point constraints exist.

45. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right] \quad \text{and} \quad [M_{nn}] = \left[\begin{array}{c|c} M_{ff} & M_{fs} \\ \hline M_{sf} & M_{ss} \end{array}\right] \ .$$

47. Equivalence $[K_{ff}]$ to $[K_{aa}]$ and $[M_{ff}]$ to $[M_{aa}]$ if no omitted coordinates exist.

49. Go to DMAP No. 53 if no omitted coordinates exist.

51. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right],$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

52. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \left[\begin{array}{c|c} \bar{M}_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right]$$

and performs matrix reduction

$$[M_{aa}] = [\bar{M}_{aa}] + [M_{oa}^T][G_o] + [G_o^T][M_{oo}][G_o] + [G_o^T][M_{oa}] \ .$$

54. Go to DMAP No. 59 if no free-body supports exist.

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55. RBMG1 partitions out free-body supports

$$[K_{aa}] = \left[\begin{array}{c|c} K_{\ell\ell} & K_{\ell r} \\ \hline K_{r\ell} & K_{rr} \end{array}\right] \quad \text{and} \quad [M_{aa}] = \left[\begin{array}{c|c} M_{\ell\ell} & M_{\ell r} \\ \hline M_{r\ell} & M_{rr} \end{array}\right] .$$

56. RBMG2 decomposes constrained stiffness matrix $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$.

57. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}],$$

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D]$$

and calculates rigid body error ratio

$$\varepsilon = \frac{||X||}{||K_{rr}||} .$$

58. RBMG4 forms rigid body mass matrix

$$[m_r] = [M_{rr}] + [M_{\ell r}^T][D] + [D^T][M_{\ell r}] + [D^T][M_{\ell\ell}][D].$$

60. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating the internal and external grid point numbers (GPLD), including extra points introduced for dynamic analysis (SILD), and prepares Transfer Function Pool (TFPØØL), and Eigenvalue Extraction Data (EED).

61. Go to DMAP No. 150 and print Error Message No. 2 if there is no Eigenvalue Extraction Data.

62. Equivalence $[G_o]$ to $[G_o^d]$ and $[G_m]$ to $[G_m^d]$ if there are no extra points introduced for dynamic analysis.

63. READ extracts real eigenvalues and eigenvectors from the equation

$$[K_{aa} - \lambda M_{aa}]\{\phi_a\} = 0 \quad ,$$

calculates rigid body modes by finding a matrix $[\phi_{ro}]$ such that

$$[m_o] = [\phi_{ro}^T][m_r][\phi_{ro}]$$

is diagonal and normalized, computes rigid body eigenvectors

$$[\phi_{ao}] = \left[\begin{array}{c} D\ \phi_{ro} \\ \hline \phi_{ro} \end{array}\right] ,$$

calculates modal mass matrix

$$[m] = [\phi_a^T][M_{aa}][\phi_a]$$

and normalizes eigenvectors according to one of the following user requests:

1) Unit value of a selected component
2) Unit value of the largest component
3) Unit value of the generalized mass.

64. ØFP formats the summary of eigenvalue extraction information (ØEIGS) prepared by READ and places it on the system output file for printing.

65. Go to DMAP No. 154 and print Error Message No. 4 if no eigenvalues were found.

66. ØFP formats the eigenvalues (LAMA) prepared by READ and places them on the system output file for printing.

67. MXTRIN selects the direct input matrices $[K^2_{pp}]$, $[M^2_{pp}]$ and $[B^2_{pp}]$.

68. Equivalence $[M^2_{pp}]$ to $[M^2_{dd}]$, $[B^2_{pp}]$ to $[B^2_{dd}]$ and $[K^2_{pp}]$ to $[K^{2d}_{dd}]$ if no constraints are applied.

69. GKAD applies constraints to direct input matrices $[K^2_{pp}]$, $[M^2_{pp}]$ and $[B^2_{pp}]$, forming $[K^2_{dd}]$, $[M^2_{dd}]$ and $[B^2_{dd}]$ and forms $[G_{md}]$ and $[G_{od}]$.

70. GKAM selects eigenvectors to form $[\phi_{dh}]$ and assembles stiffness, mass and damping matrices in modal coordinates:

$$[K_{hh}] = \left[\begin{array}{c|c} k_i & 0 \\ \hline 0 & 0 \end{array}\right] + [\phi^T_{dh}][K^2_{dd}][\phi_{dh}] \;,$$

$$[M_{hh}] = \left[\begin{array}{c|c} m_i & 0 \\ \hline 0 & 0 \end{array}\right] + [\phi^T_{dh}][M^2_{dd}][\phi_{dh}] \;,$$

$$[B_{hh}] = \left[\begin{array}{c|c} b_i & 0 \\ \hline 0 & 0 \end{array}\right] + [\phi^T_{dh}][B^2_{dd}][\phi_{dh}] \;,$$

where

KDAMP = -1 (default)	KDAMP = 1
m_i = modal masses	m_i = modal masses
$b_i = m_i \, 2\pi \, f_i \, g(f_i)$	$b_i = 0$
$k_i = m_i \, 4\pi^2 \, f_i^2$	$k_i = (1+ig(f_i)) \, 4\pi^2 \, f_i^2 m_i$

71. APD processes the aerodynamic data cards from EDT. It adds the k points and the SA points to USETD making USETA. EQAERØ, ECTA, BGPA, CSTMA, GPLA and SILA are updated to reflect the new elements. AERØ and ACPT reflect the aerodynamic parameters. SILGA is a special SIL for plotting.

74. Go to DMAP No. 81 if no plot output is requested.

76. PLTSET transforms user input into a form used to drive the structure plotter.

77. PRTMSG prints error messages associated with the structure plotter.

78. Go to DMAP No. 81 if no undeformed aerodynamic or structural element plots are requested.

79. PLØT generates all requested undeformed aerodynamic and structural element plots.

80. PRTMSG prints plotter data and engineering data for each undeformed aerodynamic and structural element plot generated.

82. GI forms a transformation matrix $[G^T_{ka}]$ which interpolates between aerodynamic (k) and structural (a) degrees of freedom.

84. AMG forms the aerodynamic matrix list $[A_{jj}]$, the area matrix $[S_{kj}]$, and the downwash coefficients $[D^1_{jk}]$ and $[D^2_{jk}]$.

85. Go to DMAP No. 87 if there are no user-supplied downwash coefficients.

86. INPUTT2 provides the user-supplied downwash factors due to extra points ($[D^1_{je}]$, $[D^2_{je}]$). PARAM NØDJE must be set to enter these matrices. The downwash w_j on box j due to the motion of an extra point, u_e, is given by

$$\{w_j\} = [D^1_{je} + ikD^2_{je}]\{u_e\} \ .$$

89. AMP computes the aerodynamic matrix list related to the modal coordinates as follows:

$$[\phi_{dh}] = \left[\begin{array}{c|c} \phi_{ai} & \phi_{ae} \\ \hline \phi_{ei} & \phi_{ee} \end{array}\right] , \qquad [G_{ki}] = [G^T_{ka}]^T[\phi_{ai}] \ ,$$

$$[D^1_{jh}] \Leftarrow [D^1_{ji} \mid D^1_{je}] \ , \qquad [D^1_{ji}] = [D^1_{jk}]^T[G_{ki}] \ ,$$

$$[D^2_{jh}] \Leftarrow [D^2_{ji} \mid D^2_{je}] \ \text{and} \qquad [D^2_{ji}] = [D^2_{jk}]^T[G_{ki}] .$$

For each (m,k) pair:

$$[D_{jh}] = [D^1_{jh}] + ik[D^2_{jh}] \ .$$

For each group:

$$[Q_{jh}] = [A^T_{jj}]^{-1}_{group} \, [D_{jh}]_{group} \ ,$$

$$[Q_{kh}] = [S_{kj}][Q_{jh}] \ ,$$

$$[Q_{ih}] = [G_{ki}]^T[Q_{kh}]$$

and $$[Q_{hh}] \Leftarrow \left[\begin{array}{c} Q_{ih} \\ \hline Q_{eh} \end{array}\right] .$$

90. FRLG forms the dynamic load vector $\{P_h\}$ from the frequency response data or transient data using a Fourier Transform.

93. GUST forms the loading due to gusts and adds to the direct loads.

94. Equivalence {PHF1} to {PHF} if there are no gust loads.

95. FRRD2 solves for the modal displacements using

$$[-M_{hh}\omega^2 + iB_{hh}\omega + K + qQ_{hh}(k)]U_h = P_h(\omega) \ .$$

96. Equivalence {UHVF} to {UHVT} and FØL to TØL if it is a frequency response formulation.

97. Go to DMAP No. 99 if it is a frequency response formulation.

98. IFT performs Inverse Fourier Transform of the displacements for transient formulation.

100. MØDACC uses data from ØFREQ or ØTIME data cards to select solutions for data recovery.

101. ADR produces aerodynamic load output (PKF) for selected points in frequency response only.

102. VDR prepares solution set displacements (ØUHV1), sorted by frequency or time, for output. The solution set includes mode amplitudes and extra points.

103. Go to DMAP No. 110 if the request is for output sorted by frequency or time step.

104. SDR3 prepares requested output sorted by solution set points.

105. ØFP formats the table prepared by SDR3 for output sorted by solution set point and places it on the system output file for printing.

106. Go to DMAP No. 110 if no X-Y plots are requested.

107. XYTRAN prepares the input for X-Y plotting of solution set points versus time or frequency.

108. Go to DMAP No. 110 if no plots are possible as requested.

109. XYPLØT prepares the requested X-Y plots of solution set points versus time or frequency.

112. Go to DMAP No. 158 if no output for physical points is requested.

113. SDR1 recovers physical displacements (PHIP) and forces of constraint (QP) for the real eigenvectors associated with the modes.

114. Equivalence $\{\phi_{dh}\}$ to $\{\phi_{ah}\}$ if there are no extra points introduced for dynamic analysis.

115. Go to DMAP No. 118 if no extra points are present.

116. VEC generates a d-size partitioning vector (EVEC) for the a- and e-sets

$$\{u_d\} \rightarrow \{u_a\} + \{u_e\} \ .$$

117. PARTN performs partition of $\{\phi_{dh}\}$ using EVEC

$$\{\phi_{dh}\} \quad \left\{\frac{\phi_{ah}}{0}\right\} \ .$$

119. MPYAD recovers the displacements at the aerodynamic points (k)

$$\{\phi_k\} = [G_{ka}^T]^T\{\phi_{ah}\} \ .$$

120. UMERGE is used to expand $\{Q_p\}$ to the ps-set.

121. UMERGE places $\{\phi_k\}$ in its proper place in the displacement vector

$$\{\phi_{pa}\} \Leftarrow \left\{\frac{\phi_{ps}}{\phi_k}\right\} .$$

122. UMERGE is used to expand $\{Q_p\}$ to the pa-set.

123. SDR2 calculates element forces (MEF1) and stresses (MES1) and prepares eigenvectors (MPHIPA1) and single-point forces of constraint (MQP1) for output sorted by frequency or time.

124. Go to DMAP No. 127 if it is not a frequency response formulation.

125. SDR2 prepares load vectors for output (ØPP1) sorted by frequency.

126. SDR3 prepares requested load output sorted by point number.

128. SDR3 prepares requested modal quantities output sorted by point number.

129. DDRMM prepares a subset of the element forces (ØEF2) and stresses (ØES2), displacement vectors (ØUPV2), and single-point forces of constraint (ØQP2) for output sorted by point number or element number.

130. ØFP formats the requested physical output prepared by DDRMM and places it on the system output file for printing.

131. Go to DMAP No. 136 if no deformed aerodynamic or structural element plots are requested.

132. MPYAD generates vectors for use by the SDR2 module.

133. SDR2 prepares vectors for deformed plotting.

134. PLØT prepares all requested deformed aerodynamic and structural element plots.

135. PRTMSG prints plotter data and engineering data for each deformed plot generated.

137. Go to DMAP No. 158 and make normal exit if no X-Y plots are requested.

138. XYTRAN prepares the input for physical point X-Y plots.

139. Go to DMAP No. 141 if no plots are possible as requested.

140. XYPLØT prepares the requested X-Y plots of displacements, forces, stresses, loads and single-point forces of the constraint versus frequency or time.

142. Go to DMAP No. 158 and make normal exit if it is a transient response formulation.

143. Go to DMAP No. 158 and make normal exit if no power spectral density functions or autocorrelation functions are requested.

144. RANDØM calculates power spectral density functions (PSDF) and autocorrelation functions (AUTØ) using the previously calculated frequency response.

145. Go to DMAP No. 158 and make normal exit if no X-Y plots of RANDØM calculations are requested.

146. XYTRAN prepares the input for requested X-Y plots of the RANDØM output.

147. Go to DMAP No. 158 and make normal exit if no plots are possible as requested.

148. XYPLØT prepares the requested X-Y plots of autocorrelation functions and power spectral density functions.

149. Go to DMAP No. 158 and make normal exit.

151. Print Error Message No. 2 and terminate execution.

153. Print Error Message No. 1 and terminate execution.

155. Print Error Message No. 4 and terminate execution.

157. Print Error Message No. 3 and terminate execution.

3.21.3 Output for Modal Aeroelastic Response

The real Eigenvalue Summary Table and real Eigenvalue Analysis Summary, as described under Normal Mode Analysis (see Section 3.4.3), are automatically printed.

The following printed output, sorted by point number or element number (SØRT2), is available, either as real and imaginary parts or as magnitude and phase angle (0° - 360° lead), for the list of frequencies or times specified by ØFREQUENCY or ØTIME (in transient formulations, these are real):

1. Displacements, velocities and accelerations for a list of PHYSICAL points (grid points and extra scalar points introduced for dynamic analysis) or SØLUTIØN points (points used in the formulation of the dynamic equation). Velocities and accelerations are not available for transient analysis.
2. Nonzero components of the applied load vector and single-point forces of constraint for a list of PHYSICAL points. Aerodynamic forces on selected aerodynamic elements.
3. Stresses and forces in selected elements (ALL available only for SØRT1).

The following printed output is available for Random Response calculations:

1. Power spectral density function and mean deviation for the response of selected components for points or elements. The expected frequency of zero crossings.
2. Autocorrelation function for the response of selected components for points or elements.

The following plotter output is available:

1. Undeformed plot of the structural model.
2. Deformed shapes of the aerodynamic and structural model for selected intervals.
3. X-Y plot of any component of displacement, velocity or acceleration of a PHYSICAL point or a SØLUTIØN point.
4. X-Y plot of any component of the applied load vector or single-point force of constraint.
5. X-Y plot of any stress or force component for an element.

The following plotter output is available for Random Response calculations:

1. X-Y plot of the power spectral density versus frequency for the response of selected components for points or elements.
2. X-Y plot of the autocorrelation versus time lag for the response of selected components for points or elements.

The data used for preparing the X-Y plots may be punched or printed in tabuar form (see Section 4.3). Also, a printed summary is prepared for each X-Y plot which includes the maximum and minimum values of the plotted function.

3.21.4 Case Control Deck for Modal Aeroelastic Response

The following items relate to subcase definition and data selection for Modal Aeroelastic Response:

1. METHØD must appear above the subcase level to select an eigenvalue extraction method.
2. At least one subcase must be defined for each unique set of direct input matrices (K2PP, M2PP, B2PP) or frequencies.
3. Consecutive subcases for each set of direct input matrices or frequencies are used to define the loading condition - one subcase for each dynamic loading condition.
4. Constraints must be defined above the subcase level.
5. DLØAD must be used to define a frequency-dependent loading condition for each subcase. If transient loads are selected, a Fourier Transform is used to compute frequency-dependent loads. All loads in one run must be of the same type.
6. FREQUENCY must be used to select one, and only one, FREQ, FREQ1, or FREQ2 card form the Bulk Data Deck. If TLØADs are selected, a TSTEP must be selected.
7. ØFREQUENCY (ØTIME) may be used above the subcase level or within each subcase to select a subset of the solution frequencies (times) for output requests. The default is to use all solution frequencies (times).
8. If Random Response calculations are desired, RANDØM must be used to select RANDPS and RANDTi cards from the Bulk Data Deck. Only one ØFREQUENCY and FREQUENCY card can be used for each set of direct input matrices.

3.21.5 Parameters for Modal Aeroelastic Response

The following parameters are used in Modal Aeroelastic Response:

1. GRDPNT - optional. A positive integer value of this parameter will cause the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.

2. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in EMA. Not recommended for use in hydroelastic problems.

3. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters will cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.

4. LFREQ and HFREQ - required unless LMØDES is used. The real values of these parameters give the frequency range (LFREQ is the lower limit and HFREQ is the upper limit) of the modes to be used in the modal formulation.

5. LMØDES - required unless LFREQ and HFREQ are used. The integer value of this parameter is the number of lowest modes to be used in the modal formulation.

6. KDAMP - optional. If set to +1, modal damping is put into a complex stiffness matrix as structural damping. The default value is -1.

7. GUSTAERØ - optional. An integer value of +1 causes gust loads to be computed. The default value is -1.

8. IFTM - optional. The value of this parameter selects the method for the integration of the Inverse Fourier Transform. The integer 0 specifies a rectangular fit; 1 specifies a trapezoidal fit; and 2 specifies a cubic spline fit to obtain solutions versus time for which aerodynamic forces are functions of frequency. The default value is 0.

9. MACH - optional. The real value of this parameter selects the closest Mach numbers to be used to compute aerodynamic matrices. The default value is 0.0.

10. Q - required. The real value of this parameter defines the dynamic pressure.

11. NØDJE - optional. A positive integer for this parameter indicates that user supplied downwash matrices due to extra points are to be read in via the INPUTT2 module in the rigid format. The default value is -1 when not needed.

12. P1, P2, and P3 - required when using the NØDJE parameter. See Section 5.5 for a description of these parameters which are required by the INPUTT2 module. The defaults for P1, P2 and P3 are 0, 11 and XXXXXXXX, respectively.

13. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.

14. AUTØSPC - reserved for future optional use. The default value is -1.

3.21.6 Optional Diagnostic Output for FEER

Special detailed information obtained by requesting DIAG 16 in the Executive Control Deck is the same as that described under Normal Mode Analysis (see Section 3.4.6).

3.21.7 The APPEND Feature

The APPEND feature can be used for real eigenvalue extraction in Modal Aeroelastic Response. See Section 3.4.7 for details.

3.21.8 Rigid Format Error Messages from Modal Aeroelastic Response

The following fatal errors are detected by the DMAP statements in the Modal Aeroelastic Response rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

MØDAL AERØELASTIC RESPØNSE ERRØR NØ. 1 - MASS MATRIX REQUIRED FØR MØDAL FORMULATION.

The mass matrix is null because either no structural elements were defined with Connection cards, nonstructural mass was not defined on a Property card or the density was not defined on a Material card.

MØDAL AERØELASTIC RESPØNSE ERRØR NØ. 2 - EIGENVALUE EXTRACTIØN DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGR card in the Bulk Data Deck and METHØD in the Case Control Deck must select an EIGR set.

MØDAL AERØELASTIC RESPØNSE ERRØR NØ. 3 - NØ GRID PØINT DATA IS SPECIFIED ØR NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No points have been defined with GRID or SPØINT cards or no structural elements have been defined with Connection cards.

MØDAL AERØELASTIC RESPØNSE ERRØR NØ. 4 - REAL EIGENVALUES REQUIRED FØR MØDAL FØRMULATIØN.

No real eigenvalues were found in the frequency range specified by the user.

4. PLOTTING

4.1 PLOTTING IN NASTRAN

NASTRAN provides the capability for generating the following kinds of plots:

1. Undeformed geometric projections of the structural model.
2. Static deformations of the structural model by either displaying the deformed shape (alone or superimposed on the undeformed shape), or displaying the displacement vectors at the grid points (superimposed on either the deformed or undeformed shape).
3. Modal deformations (sometimes called mode shapes or eigenvectors) resulting from real eigenvalue analysis by the same options stated in 2 above. Complex modes of flutter analysis may be plotted for any user chosen phase lag.
4. Deformations of the structural model for transient response or frequency response by displaying either vectors or the deformed shape for specified times or frequencies.
5. X-Y graphs of responses (displacements, velocities, accelerations, element forces and element stresses) versus time (transient response), versus frequency (frequency response) or versus subcase (static analysis).
6. V-f and V-g graphs of flutter analysis.
7. Topological displays of matrices.
8. Contour plots of stresses and displacements (in a limited fashion). To avoid crowded output, an outline of the model may be optionally requested.

Structure plots (items 1-4 and 8) are discussed in Section 4.2 while X-Y plots (items 5 and 6) are discussed in Section 4.3. Matrix plots (item 7) are generated by Utility Module SEEMAT described in Section 5.5 and must be accomplished by ALTERing this module into a rigid format DMAP sequence or by using the DMAP approach. Requests for structure plots or X-Y plots are accomplished in the Case Control Deck by submitting a structure plot request packet or an X-Y output request packet. The discussion of these packets constitutes most of the remainder of this chapter. The optional PLØTID card is considered to be a part of the plot packets, although it must precede any ØUTPUT(PLØT), ØUTPUT(XYØUT), or ØUTPUT(XYPLØT) cards (See the PLØTID card in Section 2.3).

In order to actually create plots, a physical plot tape or mass storage area must be set up by the user. There are two plot files, PLT1 and PLT2. It is only necessary to specify file PLT2. File PLT1 is reserved for future use. The system control cards needed to specify the PLT2 plot file are generally installation dependent and are described in Section 5 of the Programmer's Manual.

The NASTRAN plotting software is completely independent of any particular plotting hardware. This protects the NASTRAN software from being impacted by changes, additions or deletions made to any particular plotting hardware. Instead, the plot file produced by NASTRAN (the actual NASTRAN plot output may reside either on physical tape or on mass storage device) is meant for a hypothetical plotter termed the NASTRAN General Purpose Plotter (NASTPLT) and is not suitable for

use directly by any particular plotter. In order to use this NASTPLT file to obtain plots on any particular user's plotter, the user's installation must have available an external translator program to interpret this plot file and create plots on the user's plotter. A detailed description of the NASTPLT file is given in Section 4.4. The interested reader may also refer to Section 6.10 of the Programmer's Manual, dealing with the plotting software in NASTRAN.

The type or model of the plotting hardware on which the user will create his plots is indicated to the NASTRAN plotting software on the PLØTTER card in both structure plotting and X-Y plotting (see descriptions in Sections 4.2.2.4 and 4.3.2.5, respectively). The user may specify either a microfilm, table or drum plotter. For each of these plotter types, the user may also indicate whether the plotter has typing capability or has no typing capability. In the latter case, all characters will be drawn. The default is a microfilm plotter without typing capability.

The operation of the Structure Plotter is of sufficient theoretical content to warrant inclusion in the Theoretical Manual. Section 13 of the Theoretical Manual provides a discussion of the basic theory and gives some examples of plotter output.

The availability of NASTRAN plotting capability is a function of the particular rigid format as shown in Table 1.

4.1.1 Plot Frame Size and Character Size

The frame size of the NASTPLT plots produced by NASTRAN depends upon the model specified on the PLØTTER card. The default plot frame sizes for all the three plotter models are given in the following table.

Default Plot Frame Size for the NASTPLT Plotters

Plotter Model	Default Width (inches)	Default Height (inches)
Microfilm	10.23	10.23
Table	11.00	8.50
Drum	30.00	30.00

The plot frame size for microfilm plotters is set at the above default size and is not under user control. The frame size for the table and drum plotters can be specified by the user within

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Table 1. Plotting Availability in the NASTRAN Rigid Formats

Rigid Format	Structure Plotting		Curve Plotting	Matrix Topology Plotting
	Undeformed	Deformed		
1	x	x	x	*
2	x	x		*
3	x	x		*
4	x	x		*
5	x	x		*
6	x	x		*
7	x			*
8	x	x	x	*
9	x	x	x	*
10	x			*
11	x	x	x	*
12	x	x	x	*
13	x	x		*
14	x	x		*
15	x	x		*
1(HEAT)	x	x		*
3(HEAT)	x	x		*
9(HEAT)	x	x	x	*
10(AERØ)	x	x	x	*
11(AERØ)	x	x	x	*

* Matrix topology plotting is not automatically available in any rigid format. Utility module SEEMAT must be ALTERed into a rigid format DMAP sequence in order to use this feature (see Section 5.5).

limits, by means of the PAPER SIZE card in structure plotting (see Section 4.2.2.4) and the XPAPER and YPAPER cards in X-Y plotting (see Section 4.3.2.5).

As mentioned earlier, the NASTRAN plotting software will draw characters when the user has indicated that the plotter has no typing capability. By default, each character produced by the NASTPLT plots is assigned a space of 0.08" width by 0.16" height and within this space the character is derived from a 0.06" square. The size of the characters cannot be reduced below the default size by the user in the NASTRAN environment. However, the user can magnify the characters by the use of the CSCALE card in both structure plotting and X-Y plotting (see description in Sections 4.2.2.4 and 4.3.2.5). Note, however, that the integer factor used on the CSCALE card implies that the characters can be magnified only in discrete steps. Also note that this factor is used to multiply both the width and the height of the NASTPLT characters. Thus, a character produced with a CSCALE value of 2 will take up an area that is four times the area taken up by the default size character.

If the user wants to control the size of the characters relative to the plot, he can do so by controlling the plot frame size for a given character size. Thus, for a given CSCALE value, the size of the characters relative to the plot can be increased by decreasing the plot frame size and decreased by increasing the plot frame size.

If the user wants to scale up or down the size of both the plots and the characters produced by NASTRAN, he can do so by means of the translator program employed to create the plots. However, in this case, the size is controlled outside the NASTRAN environment.

4.2 STRUCTURE PLOTTING

In order to assist NASTRAN users both in the preparation of the analytical model and in the interpretation of output, the structure plotter provides the following capabilities for undeformed structures:

1. Place a symbol at the grid point locations. (optional)
2. Identify grid points by placing the grid point identification number to the right of the grid point locations. (optional)
3. Identify elements by placing the element identification number and element label at the center of each element. (optional)
4. Identify element properties by placing the element property identification number near the element identification number and element symbol. (optional)
5. Connect the grid points in an optional manner using structural elements or PLØTEL elements.
6. Reflect the symmetric portion of the structural elements about a designated axis. (optional).

The following capabilities are provided for deformed structures:

1. Place a symbol at the deflected grid point location. (optional)
2. Identify the deflected grid points by placing the grid point identification number to the right of the deflected grid point locations. (optional)
3. Identify elements by placing the element identification number and element label at the center of each element. (optional)
4. Identify element properties by placing the element property identification number near the element identification number and element symbol. (optional)
5. Connect the deflected grid points in an optional manner using structural elements or PLØTEL elements.
6. Draw lines originating at the undeflected or deflected grid point location, drawn to user-specified scale, representing the X, Y, Z components or resultant summations of any of the grid point deflection, velocity, or acceleration vectors.
7. Draw different portions of the structure in different parts of a frame, with different scales, labels and symbols.
8. Reflect the symmetric portion of the structural elements (which are symmetrically or antisymmetrically loaded) about a designated axis. (optional)
9. Superimpose the deflected shape over the undeflected shape. (optional)
10. Draw the outline of the structural elements which lie on the boundaries. (optional)
11. Map the deflection or stress contours of two dimensional elements in a limited fashion. (optional)

A request for structure plotting is made in the Case Control Deck by means of a plot request packet which includes all cards from an ØUTPUT(PLØT) card to either a BEGIN BULK or ØUTPUT(XYØUT) [or ØUTPUT(XYPLØT)] card. It should be noted that only elements can be plotted. (See the description

of the SET card in Section 4.2.2.4.) Grid points that are not associated with elements cannot be plotted. Grid points may be connected with PLØTEL elements for plotting purposes.

4.2.1 Structure Plotter Projections and Coordinate System

Structure plots can be obtained in any one of three projections, namely, orthographic, perspective or stereoscopic projections. (Stereoscopic plots are normally made only on microfilm plotters since a stereoscopic viewer or projector must be used to obtain the stereoscopic effect). These projections as they relate to structure plotting and the plotter coordinate system employed are described in the following sections. A theoretical treatment of the projections is given in Section 13 of the Theoretical Manual.

4.2.1.1 Orthographic Projection

The structural model is assumed to be defined in the basic coordinate system, denoted as the X, Y, Z coordinate system. The plotter (or observer's) coordinate system is defined as the R, S, T coordinate system. The direction of view is in the negative R-direction and the projection plane is always in, or parallel to, the S-T plane (see Figure 1).

The origins of the X, Y, Z and R, S, T coordinate systems are taken to be coincidental. The alignment of the X, Y, Z coordinate system with respect to the R, S, T coordinate system is prescribed by the AXES card (see description). The default alignment is for the X, Y and Z axes to align with the R, S and T axes, respectively. The orientation of the X, Y, Z coordinate system with respect to the R, S, T coordinate system is defined by the three angles α, β and γ as shown in Figure 1. These angles are prescribed by the VIEW card (see description). (As can be seen, for the default alignment, the two coordinate systems are coincident for $\alpha = \beta = \gamma = 0$).

The order in which the rotations α, β and γ are specified is critically important to determine the final orientation of the X, Y, Z system with respect to the R, S, T system as indicated in Figure 2. This order or sequence has been arbitrarily chosen as γ, the rotation about the T-axis, followed by β, the rotation about the S-axis, followed by α, the rotation about the R-axis. Normally, α is not used since it does not affect the appearance of the S-T projection, but only its orientation on the S-T plane.

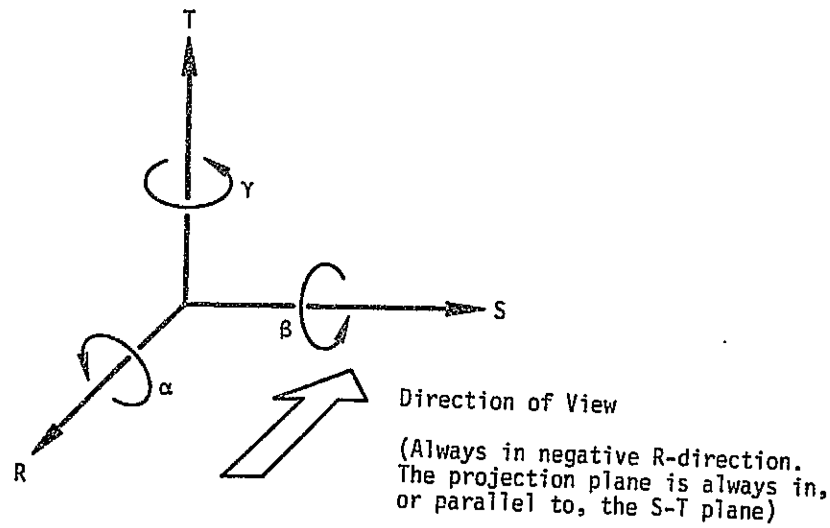
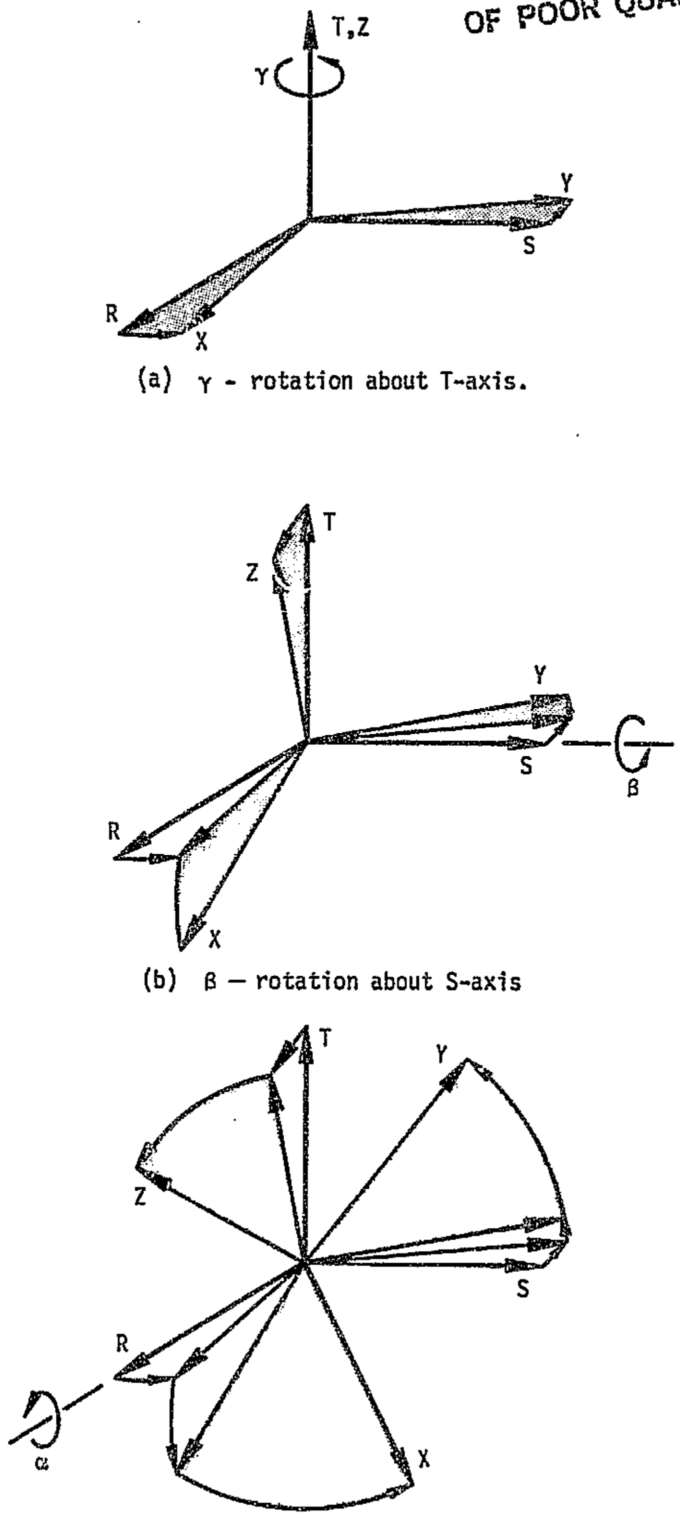


Figure 1. Plotter coordinate system



(a) γ - rotation about T-axis.

(b) β — rotation about S-axis

(c) α - rotation about R-axis

Figure 2. Plotter coordinate system-model orientation

4.2.1.2 Perspective Projection

In addition to the three angular relationships (α, β, γ) required for the orthographic projection, the perspective projection requires knowledge of the vantage point in the R, S, T system (i.e., the three coordinates of the observer) and the location of the projection plane (plotter surface). The vantage point (coordinates R_0, S_0, T_0) is either selected by the user or automatically by the program and is taken to lie in the positive R-half space. The projection plane is chosen to lie between the observer and the S-T plane. This is illustrated in Figure 3.

4.2.1.3 Stereoscopic Projection

The stereoscopic effect is obtained through the differences in images received by the left and right eyes. Each is a perspective image, but with a different vantage point. The two vantage points are separated by a distance termed the ocular separation. The user may supply this value, but the use of the default value of 70 mm (2.756 inches) is recommended since it is the nominal ocular separation standard used in commercially available stereoscopic cameras and viewers. When using this projection, the program produces two plots for viewing with a stereoscopic viewer.

4.2.2 Structure Plot Request Packet Data

4.2.2.1 Summary of Data Cards

The only structure plot data cards that are always required are the SET and PLØT cards. The FIND card is recommended for general use. All other cards are related to the definition of various parameters and are strictly optional.

The parameter cards specify how the structure will be plotted, i.e., type of projection, view angles, scales, etc. All the multiple choice parameters are defaulted to a preselected choice if not specified. If a parameter is defined more than once, the value or choice last stated (or computed) will be used. Each parameter requiring a numerical value that is not specified by the user can either be established internally in the program by means of the FIND card or can assume default values. The FIND card is used to request that the program select a SCALE, ØRIGIN, and/or VANTAGE PØINT using user-specified parameters so as to allow the construction of a plot in a user-specified region of the paper or film. All the parameters used in the generation of the various plots will be printed out as part of the output, whether they are directly specified, defaulted or established using the FIND card.

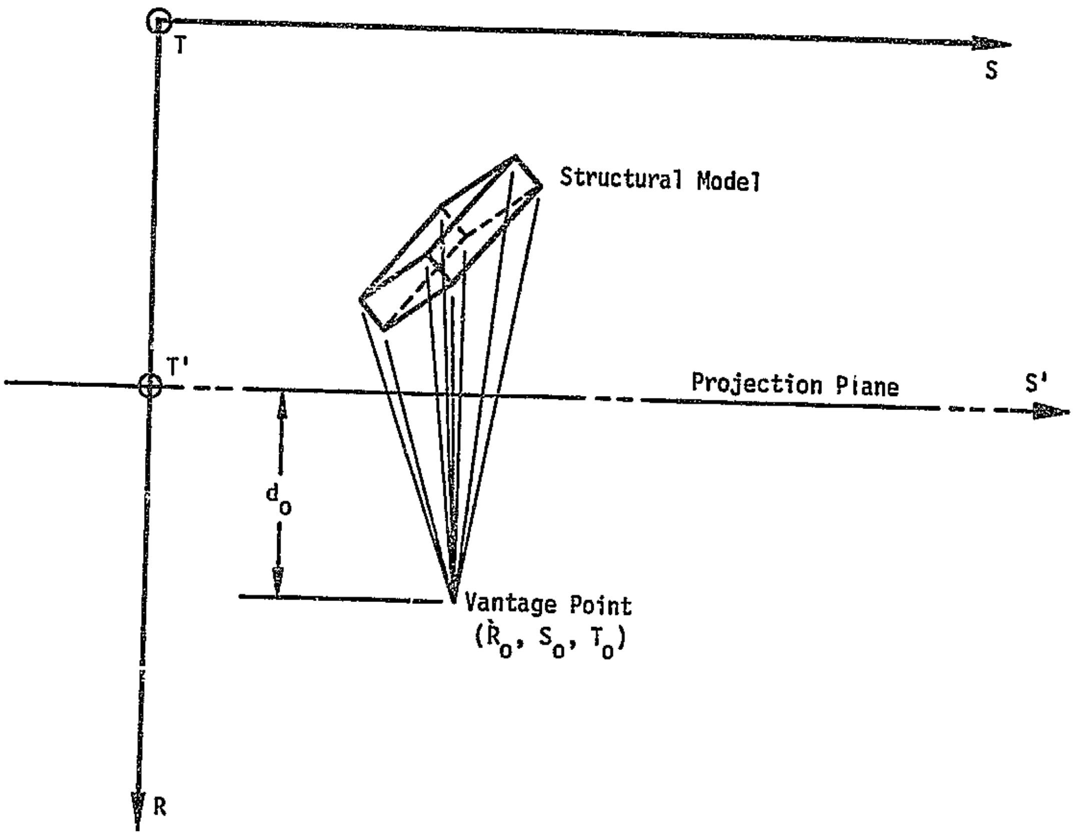


Figure 3. Perspective projection geometry

Initialization of parameters to default values occurs only once. Subsequently, these values remain until altered by a direct input. The only exceptions are the view angles, scale factors, vantage point parameters, and the origins. Whenever the plotter or the method of projection is changed, the view angles are reset to the default values, unless they are respecified by the user. In addition, the scale factors, vantage point parameters, and the origin must be redefined by the user.

The structure plot data cards are generally sequence independent, but it is important to note that the dependencies on which a FIND card or a PLØT card is based must precede these cards. Thus, for example, a SET card defining the elements and grid points to be plotted may be defined anywhere in the submittal, but it must appear prior to a FIND card or a PLØT card that references that SET. Also, if a PLØTTER card is used, it is recommended that it be the very first card in the structure plot request data after the ØUTPUT(PLØT) card in the Case Control Deck.

A summary of the data cards is given in Table 1.

4.2.2.2 Plot Titles

Up to four lines of title information will be printed in the lower left-hand corner of each plot. The text for the top three lines is taken from the TITLE, SUBTITLE, and LABEL cards in the Case Control Deck. (See Sections 2.3.2 and 2.3.4 for a description of the TITLE, SUBTITLE, and LABEL cards). The text for the bottom line may be of two forms depending on the type of plot requested. One form contains the word UNDEFØRMED SHAPE. The other form contains the type of plot (statics, modal, etc), subcase number, load set or mode number, frequency or eigenvalue or time, and (for complex quantities) the phase lag or magnitude. This information is taken from the PLØT card in the plot request packet.

Each plot frame, or group of frames, resulting from a single PLØT command may also have a line of information to the right of the SUBTITLE text. This is taken from the PTITLE card in the plot request packet.

The sequence number for each plot is printed in the upper corners of each frame. The sequence number is determined by the relative position of each PLØT execution card in the plot package. The date and (for deformed plots) the maximum deformation are also printed at the top of each frame.

Table 1. Summary of Structure Plot Data Cards

Required Cards

Name	Purpose
PLØT	Plot generation
SET	Set definition

Optional Cards

Name	Purpose	Remarks
AXES	XYZ axes alignment specification	
CAMERA	Camera specification	Used only in case of microfilm plotters
CØNTØUR	Contour plot definition	Used only if contour plots are requested
CSCALE	Character scale specification	
FIND	Automatic computation of plot parameters	Use of this card is recommended
MAXIMUM DEFØRMATIØN	Maximum displacement specification	Used only if deformed plots are requested
ØCULAR SEPARATIØN	Ocular separation definition	Used only for stereoscopic projection
ØRIGIN	Paper origin definition	Required if not on FIND card
PAPER SIZE	Plot frame size specification	Used only in case of table and drum plotters
PEN	Pen specification	Used only in case of table and drum plotters
PLØTTER	Plotter model specification	
PRØJECTIØN	Projection specification	
PRØJECTIØN PLANE SEPARATIØN	Projection plane definition	Required for perspective and and stereoscopic projections if VANTAGE PØINT is not on FIND CARD
PTITLE	Plot title definition	
SCALE	Plotted object scale definition	Required if not on FIND card
VANTAGE PØINT	Vantage point definition	Required for perspective and stereoscopic projections if not on FIND card
VIEW	XYZ axes orientation specification	

4.2.2.3 Data Card Specification Rules and Format

The format of the structure plot data cards is free-field. The following rules apply to their specification:

1. Only data in columns 1 thru 72 is processed. Any information specified in columns 73 thru 80 is ignored.
2. If the last character on a card is a comma (not necessarily in column 72), the next card is a continuation of this physical card. Any number of continuation cards may be specified, and together they form a logical card.
3. The mnemonics or values can be placed anywhere on the card, but must be separated by delimiters.
4. The following delimiters are used:
   a. blank
   b. , comma
   c. (left parenthesis
   d.) right parenthesis
   e. = equal sign

   All of these delimiters can be used as needed to aid the legibility of the data.

In the data card descriptions presented in Section 4.2.2.4, the following notations are used to describe the card format:

1. Upper-case letters must be punched exactly as shown.
2. Lower-case letters indicate that a substitution must be made.
3. Braces { } indicate that a choice of the contents is mandatory.
4. Brackets [ ] contain an option that may be omitted or included by the user.
5. Underlined options or values are those for which a default option or an initialized (or computed) value was programmed.
6. A physical card consists of information punched in columns 1 through 72 of a card.
7. A logical card may consist of more than one physical card through the use of continuation cards.

4.2.2.4 Data Card Descriptions

All of the structure plot data cards are discussed on the following pages. The descriptions are arranged in the alphabetical order of the card names. The general form for each card is shown. The description of the card contents follows. An example of each card usage is given immediately below the general form except in the case of the PLØT and SET cards where the examples follow the descriptions of the cards.

Structure Plot Data Card AXES - XYZ Axes Alignment Specification

Description: Defines the alignment of the XYZ axes (the basic coordinate system of the object) in terms of the RST axes (the observer's coordinate system). See Figure 1.

Format and Example:

$$\text{AXES} \quad \begin{Bmatrix} r \\ \underline{X} \end{Bmatrix}, \quad \begin{Bmatrix} s \\ \underline{Y} \end{Bmatrix}, \quad \begin{Bmatrix} t \\ \underline{Z} \end{Bmatrix} \quad \left[\begin{Bmatrix} \underline{\text{SYMMETRIC}} \\ \text{ANTISYMMETRIC} \end{Bmatrix}\right]$$

AXES MX, Y, MZ

Option	Meaning
r	The axis that is aligned with the R-axis (BCD). See Remark 2.
s	The axis that is aligned with the S-axis (BCD). See Remark 2.
t	The axis that is aligned with the T-axis (BCD). See Remark 2.
SYMMETRIC	Obtain an undeformed or deformed plot of the symmetric portion of an object. See Remarks 3 and 4.
ANTISYMMETRIC	Plot the deformations antisymmetrically with respect to the specified plane or planes. See Remarks 3 and 4.

Remarks:

1. This card is optional.
2. Each of the options r, s and t may have any one of the six BCD values X, Y, Z, MX, MY or MZ ("M" denotes the negative directions of the axes) so that together they represent three mutually perpendicular axes, defining a right-handed coordinate system.
3. By properly selecting the options r, s and t on the AXES card, any desired orientation can be obtained by the VIEW card (see description) by specifying rotations that are all less than 90.0°.
4. The SYMMETRIC option by itself does not in any way affect the plot output. It can be specified by the user to identify (for informational purpose only) that the alignment defined by the AXES card represents the symmetric reflection of the structure, but the actual plot of the symmetric portion can be obtained only by suitably specifying the alignment of the XYZ axes on the AXES card. See Remark 6.
5. The ANTISYMMETRIC option causes the signs of the deformations to be reversed before they are plotted. If the user wants this antisymmetrically deformed plot to appear in the reflected position with respect to one or more planes of symmetry, he should appropriately specify the alignment of the XYZ axes on the AXES card. See Remark 7.
6. An undeformed or deformed plot of the symmetric portion of an object can be obtained by reversing the sign of the axis that is normal to the plane of symmetry. In the case of multiple planes of symmetry, the signs of all associated planes should be reversed.
7. The use of the ANTISYMMETRIC option is useful when a symmetric structure is loaded in an unsymmetric manner. In this case, the user can specify the ANTISYMMETRIC option and also suitably define the alignment of the XYZ axes on the AXES card so as

(Continued)

AXES (Cont.)

to cause the deformations to be plotted antisymmetrically with respect to one or more planes of symmetry.

8. Since the AXES card applies to all parts (SETs) of a single frame, symmetric and antisymmetric combinations cannot be made with this card. The SYMMETRY and ANTISYMMETRY options on the PLØT card (see description) can be employed for that purpose.

Structure Plot Data Card CAMERA - Camera Specification

Description: Provides camera specifications for microfilm plotters.

Format and Example:

$$\text{CAMERA} \quad \left\{\begin{matrix}\text{FILM}\\ \underline{\text{PAPER}}\\ \text{BØTH}\end{matrix}\right\} \quad \left[\text{, BLANK FRAMES} \left\{\begin{matrix}n\\ \underline{1}\end{matrix}\right\}\right]$$

CAMERA FILM, 2

Option	Meaning
FILM	35 mm or 16 mm film (positive or negative images)
PAPER	Positive prints
BØTH	Positive prints and 35 mm or 16 mm film
n	Number of blanks to be inserted between plots (Integer > 0). (Applicable only to plots generated on film, i.e., only if FILM or BØTH is selected.)

Remarks: 1. This card is optional.

Structure Plot Data Card CØNTØUR - Contour Plot Definition

Description: Specifies the type of contour plot and the contour values to be plotted.

Format and Example:

```
CØNTØUR  [{stress      }] , [{EVEN 10              }] , [{Z1 }] , [{CØMMØN}]
         [{displacement}]   [{EVEN n               }]   [{Z2 }]   [{LØCAL }]
                            [{LIST c1, c2, ..., cn }]   [{MAX}]
                                                        [{MID}]
CØNTØUR MAJPRIN, EVEN 20, LØCAL
```

Option	Meaning
stress	Type of stress contour plot to be generated, any one of the following nine BCD values (see following table for applicable elements): MAJPRIN - Major principal stress (default) MINPRIN - Minor principal stress MAXSHEAR - Maximum shear stress XNØRMAL, YNØRMAL, ZNØRMAL - X, Y, Z components of the normal stress XYSHEAR, XZSHEAR, YZSHEAR - XY, XZ, YZ components of the shear stress
displacement	Type of displacement contour plot to be generated, any one of the following four BCD values (no default): XDISPLAC, YDISPLAC, ZDISPLAC - X, Y, Z components of the displacement vector (use XDISPLAC for plotting of temperatures in Heat rigid formats) MAGNITUD - Magnitude of the displacement vector
EVEN n	Contour plots will be generated for n (0 < Integer < 50) equally spaced contour values over the current range of values. The first contour value will be the minimum and the n^{th} contour value will be the maximum of the values for the current range of values. The current range of values is taken over all subcases.
LIST c1, c2,...,cn	Contour plots will be generated for the contour values ci (Real) specified in the list.
Z1	Stresses at fibre distance 1 are to be used for the contour plotting. (See following table for applicable elements.)
Z2	Stresses at fibre distance 2 are to be used for the contour plotting. (See following table for applicable elements.)
MAX	The maximum of the fibre distance 1 and fibre distance 2 stresses are to be used for the contour plotting. (See following table for applicable elements.)
MID	The average of the fibre distance 1 and fibre distance 2 stresses are to be used for the contour plotting. (See following table for applicable elements.)
CØMMØN	Transform the normal stresses and shear stresses from the local (or element)

(Continued)

CØNTØUR (Cont.)

coordinate systems (in which they are originally calculated) to a common (specifically, to the basic) coordinate system for contour plotting.

LØCAL — Leave the stresses in the local (or element) coordinate systems for contour plotting. Note that the normal Z stress and the shear XZ and shear YZ stresses are assumed to be zero in the local or element coordinate systems.

Remarks:

1. This card is optional.

2. The CØNTØUR option must be specified on the PLØT card (see description) in order to obtain contour plots.

3. The stress contour option is available only for certain element types. The applicable element types and the allowable options are shown in the following table.

Applicable Element Types and Allowable Options for Stress Contour Plots

Element Name	Stress Option	Stress Location	Coordinate System
TRIA1	MAJPRIN	Z1, Z2, or MAX	LØCAL
QUAD1	MINPRIN		LØCAL
TRPLT	MAXSHEAR		LØCAL
QDPLT	XNØRMAL		CØMMØN or LØCAL
	YNØRMAL		CØMMØN or LØCAL
	ZNØRMAL		CØMMØN
	XYSHEAR		CØMMØN or LØCAL
	XZSHEAR		CØMMØN
	YZSHEAR		CØMMØN
TRIA2	MAJPRIN	MID	LØCAL
QUAD2	MINPRIN		LØCAL
TRBSC	MAXSHEAR		LØCAL
	XNØRMAL		CØMMØN or LØCAL
	YNØRMAL		CØMMØN or LØCAL
	ZNØRMAL		CØMMØN
	XYSHEAR		CØMMØN or LØCAL
	XZSHEAR		CØMMØN
	YZSHEAR		CØMMØN
TRMEM	MAJPRIN	Z1	LØCAL
QDMEM	MINPRIN		LØCAL
QDMEM1	MAXSHEAR		LØCAL
QDMEM2	XNØRMAL		CØMMØN or LØCAL
	YNØRMAL		CØMMØN or LØCAL
	ZNØRMAL		CØMMØN
	XYSHEAR		CØMMØN or LØCAL
	XZSHEAR		CØMMØN
	YZSHEAR		CØMMØN
SHEAR	MAXSHEAR	Z1	LØCAL

4. The displacement contour option is applicable to all two-dimensional elements plotted by the structure plotter.

(Continued)

CØNTØUR (Cont.)

5. The contour lines are labeled with integers indicating the contour value. The integers are listed with their associated contour values under MESSAGES FRØM THE PLØT MØDULE in the printed output.

Structure Plot Data Card CSCALE - Character Scale Specification

Description: Specifies the scale to be used for alphanumeric characters in a structure plot.

Format and Example:

CSCALE $\begin{Bmatrix} n \\ \underline{1} \end{Bmatrix}$

CSCALE 2

Option	Meaning
n	Factor by which the normal (or default) size of alphanumeric characters is multiplied (Integer > 0).

Remarks: 1. This card is optional.

2. See Section 4.1.1 for an important discussion on plot frame size and character size.

Structure Plot Data Card FIND - Automatic Computation of Plot Parameters

Description: Computes any of the parameters SCALE, ØRIGIN i and VANTAGE PØINT indicated by the user.

Format and Example:

FIND [SCALE f] [,ØRIGIN i] [,VANTAGE PØINT] [,SET j] ,REGIØN $\left[\begin{Bmatrix} \text{le} \\ \underline{0.0} \end{Bmatrix}, \begin{Bmatrix} \text{be} \\ \underline{0.0} \end{Bmatrix}, \begin{Bmatrix} \text{re} \\ \underline{1.0} \end{Bmatrix}, \begin{Bmatrix} \text{te} \\ \underline{1.0} \end{Bmatrix}\right]$

FIND SCALE, ØRIGIN 100, VANTAGE PØINT, SET 5, REGIØN 0.3, 0.1, 0.9, 0.8

Option	Meaning
f	Ratio by which the scale is multiplied after it is calculated (Real). See Remark 6.
i	Origin identification number (Integer > 0).
j	Set identification number (Integer > 0).
le	Fractional distance of left edge of plot region from the lower left corner of the image area (Real).
be	Fractional distance of bottom edge of plot region from the lower left corner of the image area (Real).
re	Fractional distance of right edge of plot region from the lower left corner of the image area (Real).
te	Fractional distance of top edge of plot region from the lower left corner of the image area (Real).

Remarks:

1. This card is optional, but is recommended for general use.
2. Multiple FIND cards are permitted for use with different plots. Each FIND card must be one logical card.
3. This card computes any of the indicated parameters SCALE, ØRIGIN i and VANTAGE PØINT based on:
   (a) the plotter requested on the PLØTTER card,
   (b) the type of projection requested on the PRØJECTIØN card,
   (c) SET j and REGIØN le, be, re, te requested on the FIND card,
   (d) the orientation requested on the AXES and/or VIEW card(s),
   (e) the deformation scaling requested on the MAXIMUM DEFØRMATIØN card, and
   (f) the paper size requested on the PAPER SIZE card (for table and drum plotters).

   The dependencies on which a FIND card is based must precede the FIND card.

(Continued)

FIND (Cont.)

4. Any one, two, or all three of the parameters may be computed by the program by using this card, provided that the parameters not requested have already been defined. If no SET is specified on this card, the first SET defined is used by default. If no options are specified, a SCALE and VANTAGE PØINT are selected and ØRIGIN 1 is located, using the first defined SET, so that the plotted object is located within the image area. The plot region is defined as some fraction of the image area (image area = 0.0, 0.0, 1.0, 1.0. and first quadrant = 0.5, 0.5, 1.0, 1.0). The image area is located inside the margins on the paper.

5. If a parameter is defined more than once, the value or choice last stated (or computed) will be used. Because of this, it is recommended that the FIND card be inserted immediately prior to the PLØT command to which its values apply so as to ensure that previous values of the parameters are overridden.

6. The scale used in plotting (see the description of the SCALE card for the definition) is f x s, where f is the value specified on the FIND card (a default value of 1.0 is used if f is not specified) and s is the scale factor initially computed at the instance of the FIND card.

Structure Plot Data Card MAXIMUM DEFØRMATIØN - Maximum Displacement Specification

Description: Specifies the scale of the maximum displacement component in units of the structure.

Format and Example:

MAXIMUM DEFØRMATIØN d_{max}

MAXIMUM DEFØRMATIØN 5.0

Option	Meaning
d_{max}	Length to which the maximum displacement component is scaled in each subcase (Real). The value should be specified in units of the structure, not inches of paper. See Remark 3.

Remarks:

1. This card is optional and is applicable only to plots of deformed structures. It is recommended that it be used in such cases. This is because the actual deformations are usually too small to be distinguishable from the undeformed structure if they are plotted to true scale. If this card is not used, a default value of 5% of the maximum (i.e., 0.05 max (S_{max} - S_{min}, T_{max} - T_{min})) is assumed for d_{max}.

2. If the FIND card parameters are to be based on the deformed structure, the FIND card must be preceded by the MAXIMUM DEFØRMATIØN card.

3. If the MAXIMUM DEFØRMATIØN parameter d on the PLØT card (see description) is not specified, the maximum displacement component in each subcase will be scaled to a value equal to d_{max} specified on the MAXIMUM DEFØRMATIØN card. But if the

   MAXIMUM DEFØRMATIØN parameter d on the PLØT card is specified, the maximum displacement component for all subcases will be scaled to a value equal to d_{max}/d.

   Thus, in the latter case, each subcase will have a different maximum displacement component.

Structure Plot Data Card ØCULAR SEPARATIØN - Ocular Separation Definition

Description: Defines the S-direction separation of the two vantage points used in stereoscopic projection.

Format and Example:

ØCULAR SEPARATIØN $\left\{\begin{array}{c}\text{os}\\ \underline{2.756}\end{array}\right\}$

ØCULAR SEPARATIØN 2.5

Option	Meaning
os	S-direction separation (in inches) of the two vantage points used in stereoscopic projection (Real). (See the discussion in Section 4.2.1.3).

Remarks:

1. This card is optional. It is applicable only in the case of stereoscopic projection.

2. It is recommended that the default value of 2.756 inches be used. This is the separation used in standard stereoscopic cameras and viewers (70 mm).

Structure Plot Data Card ØRIGIN - Paper Origin Definition

Description: Defines the paper origin (lower left hand corner) by specifying its displacements from the RST origin.

Format and Example:

ØRIGIN i, u, v [,u']

ØRIGIN 10, 2.0, 3.0

Option	Meaning
i	Origin identification number (Integer > 0).
u	Displacement, parallel to the S-axis, of the paper origin from the RST origin (for stereoscopic projection, displacement, parallel to the S-axis, of the paper origin for the left eye from the RST origin) (Real).
v	Displacement, parallel to the T-axis, of the paper origin from the RST origin (Real).
u'	Displacement, parallel to the T-axis, of the paper origin for the right eye from the RST origin (stereoscopic projection only) (Real).

Remarks:

1. This card is optional, but is not recommended for general use. See the description of the FIND card in order to have the origin located automatically so as to place the plotted object in the center of the image area.
2. The displacements specified are in inches and are not subject to the scaling of the plotted object.
3. In the transformations performed for any of the three projections, the origins of both the object (XYZ) and the observer (RST) are assumed to be coincident.
4. Ten (10) origins are permitted to be active at any one time. However, any one can be redefined at any time. An eleventh origin is also provided if more than 10 origins are erroneously defined (i.e., only the last of these surplus origins will be retained). CAUTION: When a new projection or plotter is called for, all previously defined origins are deleted.

Structure Plot Data Card PAPER SIZE - Plot Frame Size Specification

Description: Specifies the plot frame size for table and drum plotters. (For microfilm plotters, the plot frame size is set at 10.23 inches x 10.23 inches and is not under user control.)

Format and Example:

$$\text{PAPER SIZE} \quad a \quad \begin{Bmatrix} \text{X} \\ \text{BY} \end{Bmatrix} \quad b \quad , \text{TYPE} \quad \left[\begin{Bmatrix} \text{value} \\ \underline{\text{VELLUM}} \end{Bmatrix} \right]$$

PAPER SIZE 15.0 X 12.0

Option	Meaning
a	Width (parallel to the S-axis) of plot frame in inches (Real > 0.0). Must not exceed 30.0 for table plotters.
b	Height (parallel to the T-axis) of plot frame in inches ($0.0 < b \le 30.0$).
value	Any BCD value desired by user for identification purposes.

Remarks: 1. This card is optional. If it is not used, the following default values are assumed:

Plotter Model	Default values (inches)	
	a	b
Table	11.0	8.5
Drum	30.0	30.0

2. See Section 4.1.1 for an important discussion on plot frame size and character size.

Structure Plot Data Card PEN - Pen Specification

Description: Specifies the parameters of the pen for use in table and drum plotters.

Format and Example:

$$\text{PEN} \begin{Bmatrix} i \\ \underline{1} \end{Bmatrix} \left[\text{, SIZE} \begin{Bmatrix} j \\ \underline{1} \end{Bmatrix} \right] \left[\text{, CØLØR} \begin{Bmatrix} \text{name} \\ \underline{\text{BLACK}} \end{Bmatrix} \right]$$

PEN 4, SIZE 2, CØLØR RED

Option	Meaning
i	Pen designation number (8 ≥ Integer > 0)
j	Pensize number (Integer ≥ 0)
name	Color desired (BCD)

Remarks:

1. This card is optional. It is applicable only in the case of table and drum plotters.
2. Pen designations vary on different plotters and the actual number of pens available will depend on the plotter hardware configuration at an installation. Therefore, the designation numbers used here should be regarded only as pointers to the true identification of the pens.
3. This card generates a message on the printed output which may be used for the purpose of informing the plotter operator as to what size and which color pen point to mount in the various pen holders.
4. This card does not control the pen used in generating the plot (see the PEN option on the PLØT card).

Structure Plot Data Card PLØT - Plot Generation

Description: Specifies all plot parameters so as to cause plots to be generated for the selected plotter.

Format:

```
      [ (STATIC    ) ] [ (DEFØRMATIØN ) ]                                          [ (RANGE  f1, f2) ] [ (PHASE LAG φ) ]
      [ (MØDAL     ) ] [ (VELØCITY    ) ]                                          [ (RANGE  λ1, λ2) ] [ (MAGNITUDE  ) ]  ,
PLØT  [ (CMØDAL    ) ] [ (ACCELERATIØN) ] [CØNTØUR] [i1, i2 THRU i3, etc.]         [ (TIME   t1, t2) ]
      [ (FREQUENCY ) ]
      [ (TRANSIENT ) ]
[MAXIMUM DEFØRMATIØN d],

                                                                                       [       (GRID PØINTS) ]
[SET j1][ØRIGIN k1] [ (SYMMETRY    ) ] w [ (PEN    ) ] p  [SYMBØLS m[, n]]             [ LABEL (ELEMENTS   ) ]  ,
                    [ (ANTISYMMETRY) ]   [ (DENSITY) ]                                 [       (BØTH       ) ]
                                                                                       [       (EPID       ) ]
[ (SHAPE            ) ]
[ (VECTØR v         ) ]
[ (SHAPE, VECTØR v  ) ]  ,
[ (ØUTLINE          ) ]
[ (HIDDEN           ) ]

[SET j2][ØRIGIN k2] .... etc.
```

Option	Meaning
1. STATIC	Plot static deformations in Rigid Formats 1, 2, 4, 5, 6 and 14; Heat Rigid Formats 1 and 3; Aero Rigid Format 11.
MØDAL	Plot mode shapes in Rigid Formats 3, 5, 13 and 15.
CMØDAL	Plot mode shapes in Aero Rigid Format 10.
FREQUENCY	Plot frequency deformations in Rigid Formats 8 and 11 and Aero Rigid Format 11.
TRANSIENT	Plot transient deformations in Rigid Formats 9 and 12; Heat Rigid Format 9; Aero Rigid Format 11.
2. DEFØRMATIØN	Nonzero integers(i) following refer to subcases that are to be plotted. Default is all subcases. See SHAPE and VECTOR for use of "0" command.
VELØCITY	Nonzero integers(i) following refer to subcases that are to be plotted. Default is all subcases.
ACCELERATIØN	Nonzero integers(i) following refer to subcases that are to be plotted. Default is all subcases.
3. CØNTØUR	Refers to stress or displacement contour lines and values. If deformed plots are requested, then the contours will be drawn on the deformed shape. If an underlay is requested (via "0" in the subcase string), the contours will be drawn on the undeformed shape.

(Continued)

PLØT (Cont.)

4. i1, i2, ... Nonzero integers specifying the subcases that are to be plotted. Default is all subcases. See SHAPE and VECTØR for use of "0" (underlay) command.

5. RANGE Refers to range of eigenvalues ($\lambda 1$ - $\lambda 2$; real) (Rigid Format 5) or frequencies (f1 - f2; real) (Rigid Formats 3, 8, 10, 11, 13 and 15), using requested subcases, for which plots will be prepared.

TIME Refers to time interval (t1 - t2; real), using requested subcases and output time steps, for which plots will be prepared (Rigid Formats 9 and 12).

6. PHASE LAG Real number, ϕ, in degrees (default is 0.0). The plotted value is $u_R \cos \phi - u_I \sin \phi$, where u_R and u_I are the real and imaginary parts of the response quantity (Rigid Formats 8 and 11).

MAGNITUDE Plotted value is $\sqrt{u_R^2 + u_I^2}$.

7. MAXIMUM DEFØRMATIØN Real number d. The value d_{max}/d (where d_{max} is the value specified on the MAXIMUM DEFØRMATIØN card; see description) is used as the maximum displacement component in scaling the displacements for all subcases. Each subcase is scaled separately to the value d_{max} according to its own maximum if this item is absent

8. SET Integer following (j) identifies a set which defines the portion of the structure to be plotted. Default is first set defined.

9. ØRIGIN Integer following (k) identifies the origin to be used for the plot. Default is first origin defined.

10. SYMMETRY w Prepare an undeformed or deformed plot of the symmetric portion of the object which is defined by SET j. This symmetric portion will be located in the space adjacent to the region originally defined by ØRIGIN k, and will appear as a reflection about the plane whose normal is oriented parallel to the coordinate direction w.

ANTISYMMETRY w Prepare a deformed plot of the symmetric portion of the antisymmetrically loaded object which is defined by SET j. This symmetric portion will be located in the space adjacent to the region originally defined by ØRIGIN k, and will appear as a reflection of the antisymmetrically deformed structure about the plane whose normal is oriented parallel to the coordinate direction w.

The symbol w may specify the basic coordinates X, Y or Z or any combination thereof. This option allows the plotting of symmetric and/or antisymmetric combinations, provided that an origin is selected for the portion of the structure defined by the bulk data that allows sufficient room for the complete plot. This does not permit the combination of symmetric and antisymmetric subcases, as each plot must represent a single subcase. In the case of a double reflection, the figure will appear as one reflected about the plane whose normal is parallel to the first of the coordinates w, followed by a reflection about the plane whose normal is oriented parallel to the second of the coordinates w. This capability is primarily used in the plotting of structures that are loaded in a symmetric or an antisymmetric manner. The plane of symmetry must be one of the basic coordinate planes.

In order to get both unreflected and reflected portions of a symmetric structure plotted on the same frame, the PLØT command must contain two parts. The first part must contain instructions to plot a segment with a specified origin (biased to one side), but without the SYMMETRY or ANTISYMMETRY option;

(Continued)

PLØT (Cont.)

the second part following must contain instructions to plot the same segment with the same origin, but now with an appropriate choice of the SYMMETRY or ANTISYMMETRY option. See Example 6.

11. PEN — Integer following (p) controls the internal NASTRAN pen number that is used to generate the plot on table and drum plotters.

DENSITY — Integer following (p) specifies line density for microfilm plotters. A line density of d is d times heavier than a line density of 1.

12. SYMBØLS m[,n] — All of the grid points associated with the specified set will have symbol m overprinted with symbol n printed at its location. If n is not specified, only symbol m will be printed. Grid points excluded from the set will not have a symbol. Grid points in an undeformed underlay will be identified with symbol 2.

The following table gives the correspondence between the values of m and n and the actual symbols used in plotting.

m or n	SYMBØL
0	no symbol
1	X
2	*
3	+
4	-
5	•
6	○
7	□
8	◊
9	△

13. LABEL GRID PØINTS — All the grid points associated with the specified set have their identification number printed to the right of the undeflected or deflected location (undeflected location in the case of superimposed plots).

LABEL ELEMENTS — All the elements included in the specified set are identified by the element identification number and type at the center of each element (undeflected location in the case of superimposed plots).

LABEL BØTH — Label both the grid points and elements.

(Continued)

PLØT (Cont.)

Labels for element types are given in the following table:

Element Type	Plot Label		Element Type	Plot Label
AERØ1	AE		QUAD2	Q2
AXIF2	A2		RØD	RD
AXIF3	A3		SHEAR	SH
AXIF4	A4		SLØT3	S3
BAR	BR		SLØT4	S4
CØNE	CN		TETRA	TE
CØNRØD	CR		TØRDRG	TR
DUMi	Di(i=1-9)		TRAPAX	T4
HBDY	HB		TRAPRG	TA
HEXA1	H1		TRBSC	TB
HEXA2	H2		TRIAAX	T3
FLUID2	F2		TRIARG	TI
FLUID3	F3		TRIA1	T1
FLUID4	F4		TRIA2	T2
IHEX1	XL		TRIM6	T6
IHEX2	XQ		TRMEM	TM
IHEX3	XC		TRPLT	TP
PLØTEL	PL		TRPLT1	P6
QDMEM	QM		TRSHL	SL
QDMEM1	M1		TUBE	TU
QDMEM2	M2		TWIST	TW
QDPLT	QP		VISC	VS
QUAD1	Q1		WEDGE	WG

LABEL EPID — All the elements included in the specified set are identified by the element property identification number (in addition to the element identification number and type) at the center of each element type (undeflected location in the case of superimposed plots). Note that LABEL EPID causes element and property labels to be printed, but LABEL ELEMENT results only in element labels.

14. SHAPE — All the elements included in the specified set are shown by connecting the associated grid points in a predetermined manner.

Both deformed and undeformed shapes may be specified. All of the deformed shapes relating to the subcases listed may be underlaid on each of their plots by including "0" with the subcase string on the PLØT card. The undeformed plot will be drawn using PEN 1 or DENSITY 1 and symbol 2 (if SYMBØLS is specified).

15. VECTØR v — A line will be plotted at the grid points of the set, representing in length and direction the deformation of the point.

Vectors representing the total deformation or its principal components may be plotted by insertion of the proper letter(s) for variable v. Possible vector combinations are:

X or Y or Z - requesting individual components

XY or XZ or YZ - requesting two specified components

XYZ - requesting all three components

(Continued)

PLØT (Cont.)

RXY or RXZ or RYZ - requesting vector sum of two components

R - requesting total vector deformation

N - used with any of the above combinations to request no underlay shape be drawn.

All plots requesting the VECTØR option shall have an underlay generated of the undeformed shape using the same sets, PEN 1 or DENSITY 1, and symbol 2 (if SYMBØLS is specified). If SHAPE and VECTØR are specified, the underlay will depend on whether "0" is used with DEFØRMATIØN. It will be the deformed shape when not used and will be both deformed and undeformed shapes when it is used. The part of the vector at the grid point will be the tail when the underlay is undeformed and the head when it is deformed. If the "N" parameter is used with VECTØR, no shape will be drawn but other options such as SYMBØLS will still be valid.

16. ØUTLINE — Connecting lines between grid points that lie on the boundary of the structural model will be plotted. The outline will reflect the deformed shape unless "0" is included in the subcase string. The ØUTLINE option will be ignored if the CØNTØUR option is not also requested.

17. HIDDEN — Provides a hidden image plot of the elements in the plot set. The HIDDEN option will be ignored if the CØNTØUR option is also requested. The LABEL option should not be used with the HIDDEN option.

Remarks:

1. The plot card is required to generate plots. Each logical card will cause one picture to be generated for each subcase, mode or time step requested, using the current parameter values.

2. If only the word PLØT appears on the card, a picture of the undeformed structure will be prepared using the first defined set and the first defined origin.

Examples:

Following are some examples illustrating the use of the PLØT card:

1. PLØT

   Undeformed SHAPE using first defined SET, first defined ØRIGIN and PEN 1 (or DENSITY 1).

2. PLØT SET 3 ØRIGIN 4 PEN 2 SHAPE SYMBØLS 3 LABEL

   Undeformed SHAPE using SET 3, ØRIGIN 4, PEN 2 (or DENSITY 2) with each grid point of the set having a + placed at its location, and its identification number printed adjacent to it.

3. PLØT MØDAL DEFØRMATIØN 5 SHAPE

   Modal deformations as defined in subcase 5 using first defined SET, first defined ØRIGIN, and PEN 1 (or DENSITY 1). Subcases must have previously been defined in the Case Control Deck via the use of MØDES cards, otherwise all modes will be in an assumed subcase 1.

4. PLØT STATIC DEFØRMATIØN 0, 3 THRU 5, 8 PEN 4, SHAPE

   Static deformations as defined in subcases 3, 4, 5 and 8, deformed SHAPE; drawn with

(Continued)

PLØT (Cont.)

PEN 4, using first defined SET and ØRIGIN, underlayed with undeformed SHAPE drawn with PEN 1. This command will cause four plots to be generated.

5. PLØT STATIC DEFØRMATIØN 0 THRU 5,

   SET 2 ØRIGIN 3 PEN 3 SHAPE,

   SET 2 ØRIGIN 4 PEN 4 VECTØRS XYZ SYMBØLS 6,

   SET 35 SHAPE

   Deformations as defined in subcases 1, 2, 3, 4 and 5, undeformed underlay with PEN 1, consisting of SET 2 at ØRIGIN 3, SET 2 at ØRIGIN 4 (with an * placed at each grid point location), and SET 35 at ØRIGIN 4. Deflected data as follows: SHAPE using SET 2 at ØRIGIN 3 (PEN 3) and SET 35 at ØRIGIN 4 (PEN 4); 3 VECTØRS (X, Y and Z) drawn at each grid point of SET 2 at ØRIGIN 4 (PEN 4) (less any excluded grid points), with O placed at the end of each vector.

6. PLØT STATIC DEFØRMATIØNS 0, 3, 4,

   SET 1 ØRIGIN 2 DENSITY 3 SHAPE,

   SET 1 SYMMETRY Z SHAPE,

   SET 2 ØRIGIN 3 SHAPE,

   SET 2 SYMMETRY Z SHAPE

   Static deformations as defined in subcases 3 and 4, both halves of a problem solved by symmetry using the X-Y principal plane as the plane of symmetry. SET 1 at ØRIGIN 2 and SET 2 at ØRIGIN 3, with the deformed shape plotted using DENSITY 3 and the undeformed structure plotted using DENSITY 1. The deformations of the "opposite" half will be plotted to correspond to symmetric loading. This command will cause two plots to be generated.

7. PLØT TRANSIENT DEFØRMATIØN 1, TIME 0.1, 0.2, MAXIMUM DEFØRMATIØN 2.0, SET 1, ØRIGIN 1, PEN 2, SYMBØLS 2, VECTØR R

   Transient deformations as defined in subcase 1 for time = 0.1 to time = 0.2, using SET 1 at ØRIGIN 1. The undeformed shape using PEN or DENSITY 1 with an * at each grid point location will be drawn as an underlay for the resultant deformation vectors using PEN or DENSITY 2 with an * typed at the end of each vector drawn. In addition, a plotted value of $d_{max}/2.0$ (where d_{max} is the value specified on the MAXIMUM DEFØRMATIØN card) will be used for the single maximum deformation occuring on any of the plots produced. All other deformations on all other plots will be scaled relative to this single maximum deformation. This command will cause a plot to be generated for each output time step which lies between 0.1 and 0.2.

8. PLØT CMØDAL DEFØRMATIØN PHASE LAG 90., SET 1 VECTØR R

   The imaginary part of the complex mode shape will be plotted for SET 1.

9. PLØT CØNTØUR 2

   PLØT CØNTØUR 2 ØUTLINE

   CØNTØUR MINPRIN

(Continued)

PLØT (Cont.)

PLØT STATIC DEFØRMATIØN CØNTØUR 1 ØUTLINE

The first PLØT card will cause Major Principal Stress contours to be plotted on the undeformed shape of the complete model and the second PLØT card will cause the outline of the model to be plotted due to the defaults associated with the CØNTØUR card. Contour stress plots of the Minor Principal Stress will be plotted on the outline of the deformed shape by the third PLØT card.

Structure Plot Data Card PLØTTER - Plotter Model Specification

Description: Specifies the model and the typing capability of the plotter to be used for plotting.

Format and Example:

$$\text{PLØTTER NASTPLT} \left[\text{, [MØDEL]} \begin{Bmatrix} \underline{M} \\ T \\ D \end{Bmatrix} \text{,} \begin{Bmatrix} 0 \\ \underline{1} \end{Bmatrix} \left[\text{DENSITY} \quad N \quad \text{BPI} \right] \right]$$

PLØTTER NASTPLT, T, 0

Option	Meaning
M	Microfilm plotter
T	Table plotter
D	Drum , otter
0	Plotter has typing capability
1	Plotter has no typing capability. In this case, all characters will be drawn.
N	Density of the plot tape in bits per inch (Integer > 0).

Remarks:

1. This card is optional. If it is used, it is recommended that it be the very first card after the ØUTPUT(PLØT) card in the structure plot request packet.

2. The tape density information is used only in the printout and does not control the density of the generated plot tape. To actually specify the tape density, the user must use the customary means of communication established at a given installation between the user and the computer operators.

Structure Plot Data Card PRØJECTIØN - Projection Specification

Description: Specifies the type of projection to be used in the plotting.

Format and Example:

$$\left\{\begin{array}{l}\text{ØRTHØGRAPHIC} \\ \text{PERSPECTIVE} \\ \text{STEREØSCØPIC}\end{array}\right\} \quad \text{PRØJECTIØN}$$

PERSPECTIVE PRØJECTIØN

Remarks:
1. This card is optional.
2. See Section 4.2.1 for a discussion of the various projections. See also Section 13 of the Theoretical Manual.

Structure Plot Data Card PRØJECTIØN PLANE SEPARATIØN - Projection Plane Definition

Description: Specifies the R-direction separation of the observer and the projection plane in perspective and stereoscopic projections.

Format and Example:

PRØJECTIØN PLANE SEPARATIØN d_o

PRØJECTIØN PLANE SEPARATIØN 5.0

Option	Meaning
d_o	R-direction separation of the observer and the projection plane (Real).

Remarks:

1. This card is optional. It is applicable only in the case of perspective and stereoscopic projections. See Figure 3 and the discussion in Section 4.2.1.
2. This card is not recommended for general use. It may be omitted if VANTAGE PØINT is included on the FIND card (see description).
3. See Section 13 of the Theoretical Manual for a theoretical discussion of the projection plane separation.

Structure Plot Data Card PTITLE - Plot Title Definition

Description: Defines the plot title for a series of plots.

Format and Example:

$$\text{PTITLE}\quad\begin{bmatrix}\text{blanks}\\ \text{BCD string}\end{bmatrix}$$

PTITLE VIBRATION ANALYSIS OF A PLATE

Option	Meaning
BCD string	May be up to 64 characters.

Remarks: 1. This card is optional.

2. A plot title card remains in effect until a new plot title is defined. To eliminate a previous plot title, a new plot title card which contains only blanks must be defined.

3. A plot title card must precede the PLØT card to which it pertains. If a PLØT card generates several plot frames, the preceding plot title card will apply to all the frames.

Structure Plot Data Card <u>SCALE</u> - Plotted Object Scale Definition

<u>Description</u>: Defines the scale of the plotted object with respect to the real object.

<u>Format and Example</u>:

SCALE a [,b]

SCALE 0.5, 0.75

<u>Option</u>	<u>Meaning</u>
a	Ratio of the plotted object in inches to the real object (in the case of orthographic or perspective projections) or a smaller model (in the case of stereoscopic projection; see below) in the units of the structural model, i.e., one inch of paper equals one unit of the structure (Real).
b	Ratio by which the real object is first reduced to a smaller model before applying the scale factor "a" described above (Real). Used only in stereoscopic projections to enhance the stereoscopic effect.

<u>Remarks</u>:

1. This card is optional, but is <u>not</u> recommended for general use. See the description of the FIND card in order to have the scale determined automatically.
2. In the case of stereoscopic projections, the ratio of the plotted object to the real object is given by the product a x b.

Structure Plot Data Card SET - Set Definition

Description: Specifies sets of elements, corresponding to portions of the structure, which may be referenced by FIND and PLØT cards.

Format:

SET i [INCLUDE] [ELEMENTS] j_1, j_2, j_3 THRU j_4, j_5, etc.

[INCLUDE / EXCLUDE / EXCEPT] [ELEMENTS / GRID PØINTS] k_1, k_2, k_3 THRU k_4, k_5, etc.

Option	Meaning
i	Set identification number (Integer > 0)
j	Element identification numbers (Integers > 0) or element types (BCD values)
k	Element identification numbers or grid point identification numbers (Integers > 0) or element types (BCD values)

Remarks:

1. This card is required.
2. Multiple SET cards can be used to define multiple sets of elements, but redefinition of previously defined SETs is not permitted. Also, each SET must be one logical card and each SET identification number must be unique.
3. ALL may be used to select all permissible element types. The following are the permissible element types:

   AERØ1, AXIF2, AXIF3, AXIF4, BAR, CØNEAX, CØNRØD, DUMi (i = 1-9), HBDY, HEXA1, HEXA2, FLUID2, FLUID3, FLUID4, IHEX1, IHEX2, IHEX3, PLØTEL, QDMEM, QDMEM1, QDMEM2, QDPLT, QUAD1, QUAD2, RØD, SHEAR, SLØT3, SLØT4, TETRA, TØRDRG, TRAPAX, TRAPRG, TRBSC, TRIAAX, TRIARG, TRIA1, TRIA2, TRIM6, TRMEM, TRPLT, TRPLT1, TRSHL, TUBE, TWIST, VISC, WEDGE.
4. INCLUDE may be used at any time for element information. When used with grid points, INCLUDE can be used only to restore previously EXCLUDEd grid points. It cannot be used to include grid points in the original set of grid points.
5. EXCLUDE can be used to delete elements or element types. All grid points that are associated with deleted elements are also deleted. EXCLUDE can be used to delete deformation vectors from grid points enumerated after an EXCLUDE command.
6. EXCEPT is a modifier to an INCLUDE or an EXCLUDE statement.
7. THRU is used to indicate all of the integers in a sequence of identification numbers, starting with the integer preceding THRU and ending with the integer following THRU. The integers in the range of the THRU statement need not be consecutive, e.g., the sequence 2, 4, 7, 9 may be specified as 2 THRU 9.
8. Each set of elements defines by implication a set of grid points connected by those elements. The set may be modified by deleting some of its grid points. The elements are used for creating the plot itself and element labeling while the grid points are used for labeling, symbol printing, and drawing deformation vectors.

(Continued)

SET (Cont.)

9. It should be noted that only elements can be plotted. Grid points not associated with elements cannot be plotted. Grid points may be connected with PLØTEL elements for plotting purposes.

10. When using axisymmetric (CØNEAX, TRAPAX or TRIAAX) or fluid (FLUID2, FLUID3 or FLUID4) elements, the element and grid point identification numbers specified on the SET card must refer to the NASTRAN (or internal) identification numbers rather than to the user (or external) identification numbers. The relationships between these two sets of identification numbers are given in Section 1.3.7.3 for the axisymmetric elements and in Section 1.7.1.4 for the fluid elements.

Examples:

The sets of identification numbers can be assembled by use of the word ALL, or by individually listing the integers in any order such as 1065, 32, 46, 47, 7020, or by listing sequences using THRU, EXCLUDE, and EXCEPT such as 100 THRU 1000 EXCEPT 182 EXCLUDE 877 THRU 911. Following are some examples of SET cards:

1. SET 1 INCLUDE 1, 5, 10 THRU 15 EXCEPT 12
   (Set will consist of elements 1, 5, 10, 11, 13, 14 and 15)

2. SET 25 = RØD, CØNRØD, EXCEPT 21
   (Set will consist of all RØD and CØNRØD elements except element 21)

3. SET 10 SHEAR EXCLUDE GRID PØINTS 20, 30 THRU 60, EXCEPT 35, 36 INCLUDE ELEMENTS 70 THRU 80
   (This set will include all SHEAR elements plus elements 70 thru 80, and the associated grid point set will contain all grid points connected by these elements. Grid points 20, 30 thru 34 and 37 thru 60 will appear on all plots with their symbols and labels, however, no deformation vectors will appear at these grid points when VECTØR is commanded.

4. SET (15) = (15 THRU 100) EXCEPT (21 THRU 25)
   (This set will include all elements from 15 to 20 and from 26 to 100).

5. SET 2 = ALL EXCEPT BAR
   (This set will include all elements except BARs).

NOTE: The equal signs, commas, and parentheses above are delimiters and are not required because blanks also serve as delimiters.

Structure Plot Data Card VANTAGE PØINT - Vantage Point Definition

Description: Defines the location of the observer with respect to the structural model by defining the vantage point(s) used in perspective and stereoscopic projections.

Format and Example:

VANTAGE PØINT r_o, s_o, t_o [,s_{or}]

VANTAGE PØINT 2.0, 5.0, 0.0

Option	Meaning
r_o	R-coordinate of the observer (Real).
s_o	S-coordinate of the observer in perspective projection or the S-coordinate of the left eye of the observer in stereoscopic projection (Real).
t_o	T-coordinate of the observer (Real).
s_{or}	S-coordinate of the right eye of the observer in stereoscopic projection (not needed in perspective projection) (Real).

Remarks:

1. This card is optional. It is applicable only in the case of perspective and stereoscopic projections. See Figure 3 and the discussion in Section 4.2.1.
2. This card is not recommended for general use. See the description of the FIND card in order to have the VANTAGE PØINT(s) determined automatically.
3. See Section 13 of the Theoretical Manual for a theoretical description of the vantage point.

Structure Plot Data Card VIEW - XYZ Axes Orientation Specification

Description: Defines the orientation of the XYZ axes (the basic coordinate system of the object) with respect to the RST axes (the observer's coordinate system). See Figures 1 and 2.

Format and Example:

VIEW $\left\{ \begin{matrix} \gamma \\ \underline{34.27} \end{matrix} \right\}$, $\begin{matrix} \beta \\ \underline{23.17} \text{ or } \underline{0.0} \\ \text{(See Remark 2)} \end{matrix}$, $\left\{ \begin{matrix} \alpha \\ \underline{0.0} \end{matrix} \right\}$

VIEW 45.0, 30.0, 0.0

Option	Meaning
γ	Angle of turn (degrees) (Real). See Figures 1 and 2.
β	Angle of tilt (degrees) (Real). See Figures 1 and 2.
α	Angle of orientation (degrees) (Real). See Figures 1 and 2.

Remarks:

1. This card is optional.
2. The default value for β is 23.17° for orthographic and perspective projections and 0.0° for stereoscopic projections.
3. The order in which γ, β and α are specified is critically important as illustrated in Figure 3. See also Section 13.1.1 of the Theoretical Manual.
4. By proper use of the AXES card (see description), any desired orientation can be obtained by the VIEW card by specifying rotations that are all less than 90.0°.

4.2.3 Error Messages

The structure plotting software in NASTRAN contains messages related to plot requests that are not in the same format as the other diagnostic messages described in Section 6. These messages are warnings and notify the user that the erroneous plot requests are being ignored. Only legitimate plot requests, if any, will be honored.

The messages and their meanings are as follows:

1. NØ PLØTTABLE STRUCTURAL ELEMENTS EXIST IN SET ********.

   This message is issued when a SET contains elements that are not permitted as described in Section 4.2.2.4. If a SET has some elements that are plottable and some that are not, the message is not issued and the resulting plot contains only the plottable elements.

2. ALL REFERENCES TØ SET ******** WILL DEFAULT TØ FIRST SET DEFINED.

   This message is issued when a SET referenced on a PLØT card either does not exist or has been eliminated previously due to another error.

3. REFERENCE TØ SET ******** ØN FIND CARD WILL DEFAULT TØ FIRST DEFINED SET.

   This message is issued when a SET referenced on a FIND card either does not exist or has been eliminated previously due to another error.

4. MAXIMUM DEFØRMATIØN CARD NEEDED - 5 PER CENT ØF MAXIMUM DIMENSIØN USED.

   This message is issued when the MAXIMUM DEFØRMATIØN card is not positioned properly in the plot request package or has not been defined.

5. AN UNRECØGNIZABLE ØPTIØN (********) WAS DETECTED ON A -PLØT- CARD.

   This message is issued when illegal, out of sequence, or mispelled options appear on a PLØT card. The plot will be prepared, if possible, from the remaining information.

6. A NØN-EXISTENT ØRIGIN (********) HAS BEEN SPECIFIED ØN A -PLØT- CARD.

   This message is issued when an ØRIGIN has not been defined or has been previously eliminated by another error.

7. A NØN-EXISTENT SET (********) HAS BEEN SPECIFIED ØN A -PLØT- CARD.

   This message is issued when a SET has not been defined or has been previously eliminated by another error.

8. THE -****- PLØT FILE HAS NØT BEEN SET UP...PLØT CARD IGNØRED

   This message is issued when the plot file has not been assigned to tape or disk. No plots possible.

9. INSUFFICIENT CØRE FØR SET (********). CØRE AVAILABLE = ********, NEEDED = ********.

   This message is issued when insufficient core is available to process the SET defined. Either increase the core or reduce the size of the SET to subSETs.

10. *** A PLØT NØT ATTEMPTED DUE TØ INPUT ØR FILE ***.

    This message is issued when a PLØT command contradicts Case Control. For example, requesting plots for a SUBCASE, EIGENVALUE, LØAD, TIME, or FREQUENCY that does not exist would be contradictory. No plots possible.

11. *** INCØMPLETE PLØT DUE TØ INPUT ØR FILE ***.

    This message is issued for the same reasons as in the preceding message, except some plotting is possible because not all plot requests are contradictory.

12. NØ STRESS CALCULATIØN FØUND FØR ELEMENT NUMBER ******** ELEMENT IGNØRED.

    This message is issued when a STRESS contour plot is requested but STRESS computations were not requested in Case Control.

13. MØRE THAN 50 CØNTØURS SPECIFIED *** REJECTED.

    This message is issued for all contour plot requests beginning with the fifty-first request.

14. AN ATTEMPT HAS BEEN MADE TØ DEFINE MØRE THAN *** DISTINCT ØRIGINS.

15. AN UNRECØGNIZABLE PLØT PARAMETER HAS BEEN DETECTED - IGNØRED.

4.3 X-Y OUTPUT

In rigid formats used for transient response, frequency response (including random response), modal flutter analysis and modal aeroelastic response, the amount of output data generated is voluminous. In order to aid the user in assimilating this vast amount of data, the X-Y output processing modules XYTRAN and XYPLØT have been provided. The primary purpose of these modules is to generate plotted graphs of y(x) where x is frequency, time, or velocity and y is any response quantity selected by the user for observation. (These modules also provide for the plotting of any response quantity selected by the user versus subcase in static analysis (Rigid Format 1)). The user is not required to specify any parametric data for the X-Y plotter; however, he may do so if he wishes in order to obtain desired scales, regions of observation, etc.

In addition to (or in place of) the plots, X-Y tabular output may be printed or punched, and summary data (e.g., maximum and minimum values and locations of these values) may be obtained for any X-Y output. There is also provision to generate X-Y plots within the printed output.

The X-Y output described above is obtained by the user via the X-Y output request packet of the Case Control Deck. This packet includes all cards between ØUTPUT(XYPLØT) [or (XYØUT)] and either BEGIN BULK or ØUTPUT(PLØT). The remainder of this section describes the X-Y output request data cards and the rules for writing them. Examples are provided to illustrate the use of this feature.

4.3.1 X-Y Plotter Terminology

A single set of plotted X-Y pairs is known as a "curve". Curves are the entities that the user requests to be plotted. The surface (paper, microfilm frame, etc) on which one or more curves is plotted is known as a "frame". Curves may be plotted on a whole frame, an upper half frame, or a lower half frame. Grid lines, tic marks, axes, axis labeling and other graphic control items may be chosen by the user. The program will select defaults for parameters not selected by the user.

4.3.2 X-Y Output Request Packet Data

4.3.2.1 Summary of Data Cards

Only two cards are required for an X-Y output request. These are:

1. X-Y output request packet identifier - ØUTPUT(XYPLØT) or ØUTPUT(XYØUT).
2. At least one command operation card.

The terms ØUTPUT(XYPLØT) and ØUTPUT(XYØUT) are interchangeable and either form may be used for any of the X-Y output requests. A plotter selection card is required only if plots are desired and the

plotter is other than the default plotter (microfilm plotter without typing capability). The command operation cards are used to request the various forms of X-Y output. For the sake of convenience and completeness, all command operation cards are described together under the description of the XYPLØT data card in Section 4.3.2.5.

If only the required cards are used, the graphic control items will all assume default values. Curves using all default parameters have the following general characteristics:

1. Tic marks are drawn on all edges of the frame. Five spaces are provided on each edge of the frame.
2. All tic marks are labeled with their values.
3. Linear scales are used.
4. Scales are selected such that all points fall within the frame.
5. The plotted points are connected with straight lines.
6. The plotted points are not identified with symbols.

The above characteristics may be modified by inserting any of the parameter definition cards, described in Section 4.3.2.5, ahead of the command operation card or cards. The use of a parameter definition card sets the value of that parameter for all following command operation cards unless the CLEAR card is inserted. (Because of its impact, the user should be very careful in the use of the CLEAR card. See its description for details). If grid lines are requested, they will be drawn at the locations of all tic marks that result from defaults or user request. The locations of tic marks (or grid lines) for logarithmic scales cannot be selected by the user. Default values for logarithmic spacing are selected by the program. The default values for the number of tic marks (or grid lines) per cycle depend on the number of logarithmic cycles required for the range of the plotted values.

A summary of the data cards is given in Table 1.

4.3.2.2 Tic Marks in Plots

Tic marks on any edge can be selected by the use of the appropriate "TICS" parameter cards (UPPER TICS, LØWER TICS, LEFT TICS, RIGHT TICS, TLEFT TICS, TRIGHT TICS, BLEFT TICS and BRIGHT TICS). Thus, on any edge, the user can select any one of the following options:

(a) tic marks to be drawn without values,

(b) no tic marks or values to be drawn, or

(c) tic marks to be drawn with values.

It is, however, very important to note that the results yielded by the use of the above

Table 1. Summary of X-Y Output Data Cards

Cards Pertaining to All Plots	
1	CAMERA
2	CLEAR
3	CSCALE
4	CURVELINESYMBØL
5	DENSITY
6	LØWER TICS
7	PENSIZE
8	PLØTTER
9	SKIP
10	TCURVE
11	UPPER TICS
12	XDIVISIØNS
13	XINTERCEPT
14	XLØG
15	XMAX
16	XMIN
17	XPAPER
18	XTITLE
19	XVALUE PRINT SKIP
20	YAXIS
21	YPAPER

Cards Pertaining to Various Frame Plots			
	Whole Frame Only	Upper Half Frame Only	Lower Half Frame Only
1	ALLEDGE TICS	TALL EDGE TICS	BALL EDGE TICS
2	LEFT TICS	TLEFT TICS	BLEFT TICS
3	RIGHT TICS	TRIGHT TICS	BRIGHT TICS
4	XAXIS	XTAXIS	XBAXIS
5	XGRID LINES	XTGRID LINES	XBGRID LINES
6	YDIVISIØNS	YTDIVISIØNS	YBDIVISIØNS
7	YGRID LINES	YTGRID LINES	YBGRID LINES
8	YINTERCEPT	YTINTERCEPT	YBINTERCEPT
9	YLØG	YTLØG	YBLØG
10	YMAX	YTMAX	YBMAX
11	YMIN	YTMIN	YBMIN
12	YTITLE	YTTITLE	YBTITLE
13	YVALUE PRINT SKIP	YTVALUE PRINT SKIP	YBVALUE PRINT SKIP

Command Operation Cards	
1	XYPAPLØT
2	XYPEAK
3	XYPLØT
4	XYPRINT
5	XYPUNCH

mentioned "TICS" cards may be altered when they are used in conjunction with ALLEDGE TICS, TALL EDGE TICS or BALL EDGE TICS cards. Noting that the tic values input may only be -1, 0 or 1, the net result of the use of various "TICS" cards may be determined by the following procedure:

Add the tic integer value of the edge in question to its associated ALLEDGE TICS, TALL EDGE TICS or BALL EDGE TICS integer value. Let the resulting value be termed "ticsum". Then we have the following:

If ticsum < 0, tic marks will be drawn without values.

If ticsum = 0, no tic marks or values will be drawn.

If ticsum > 0, tic marks will be drawn with values.

The user should therefore be careful in his use of the ALLEDGE TICS, TALL EDGE TICS or BALL EDGE TICS cards. Thus, the use of only the ALLEDGE TICS = -1 card will result in no tic marks or values being drawn since the default values for individual edge tic cards are all +1.

4.3.2.3 Plot Titles

Each frame, or group of frames, resulting from a single XYPLØT command will include the information from the TITLE, SUBTITLE, and LABEL cards in the Case Control Deck, the frame sequence number, and the date as described in Section 4.2.2.2. Other titling information relative to axes and curves is discussed in Section 4.3.2.5 under the descriptions of the individual X-Y output data cards.

4.3.2.4 Data Card Specification Rules and Format

The format of the X-Y output data cards is free-field. The rules governing their specifications and the notations used to describe their format are the same as those described in Section 4.2.2.3 for structure plot data cards. There is, however, an important addition to the manner in which an X-Y output command operation card can be continued: if continuation cards are needed in the case of the command operation cards, the previous card must be terminated either by a slash (/) or by a comma.

4.3.2.5 Data Card Descriptions

All of the X-Y output data cards are described on the following pages. The descriptions are arranged in the alphabetical order of the card names. The general form for each card is shown. The description of the card contents then follows. An example of each card usage is given immediately below general form, except in the case of the XYPLØT card where the examples follow the description of the card.

X-Y Output Data Card ALLEDGE TICS - All Edge Tic Request

Description: Requests use of tic marks on all edges of whole frame plots only.

Format and Example:

ALLEDGE TICS = $\left\{\begin{array}{c}-1\\0\\\underline{1}\end{array}\right\}$

ALLEDGE TICS = 0

Option	Meaning
-1	Draw tic marks without values on all edges. See Remark 2 below.
0	Do not draw either tic marks or values on any edge. See Remark 2 below.
1	Draw tic marks with values on all edges. See Remark 2 below.

Remarks:

1. This card is optional. It pertains only to whole frame plots.
2. When this card is used, the effects of other "TICS" cards may be altered. See Section 4.3.2.2 for details.

X-Y Output Data Card BALL EDGE TICS - All Edge Tic Request

Description: Requests use of tic marks on all edges of lower half frame plots only.

Format and Example:

$$\text{BALL EDGE TICS} = \begin{Bmatrix} -1 \\ 0 \\ \underline{1} \end{Bmatrix}$$

BALL EDGE TICS = 0

Option	Meaning
-1	Draw tic marks without values on all edges. See Remark 2 below.
0	Do not draw either tic marks or values on any edge. See Remark 2 below.
1	Draw tic marks with values on all edges. See Remark 2 below.

Remarks:

1. This card is optional. It pertains only to lower half frame plots.
2. When this card is used, the effects of other "TICS" cards may be altered. See Section 4.3.2.2 for details.

X-Y Output Data Card BLEFT TICS - Left Edge Tic Request

Description: Requests use of tic marks on the left edge of lower half frame plots only.

Format and Example:

BLEFT TICS = $\left\{\begin{matrix} -1 \\ 0 \\ \underline{1} \end{matrix}\right\}$

BLEFT TICS = 0

Option	Meaning
-1	Draw tic marks without values on the left edge. See Remark 2 below.
0	Do not draw either tic marks or values on the left edge. See Remark 2 below.
1	Draw tic marks with values on the left edge. See Remark 2 below.

Remarks:
1. This card is optional. It pertains only to lower half frame plots.
2. The above meanings for the options may be altered when BALL EDGE TICS card is also used. See Section 4.3.2.2 for details.

X-Y Output Data Card BRIGHT TICS - Right Edge Tic Request

Description: Requests use of tic marks on the right edge of lower half frame plots only.

Format and Example:

BRIGHT TICS = $\begin{Bmatrix} -1 \\ 0 \\ \underline{1} \end{Bmatrix}$

BRIGHT TICS = 0

Option	Meaning
-1	Draw tic marks without values on the right edge. See Remark 2 below.
0	Do not draw either tic marks or values on the right edge. See Remark 2 below.
1	Draw tic marks with values on the right edge. See Remark 2 below.

Remarks:
1. This card is optional. It pertains only to lower half frame plots.
2. The above meanings for the options may be altered when BALL EDGE TICS card is also used. See Section 4.3.2.2 for details.

X-Y Output Data Card CAMERA - Camera Specification

Description: Specifies the camera for microfilm plotters.

Format and Example:

$$\text{CAMERA} = \left\{\begin{array}{l}\text{FILM}\\ \text{PAPER}\\ \underline{\text{BØTH}}\\ 1\\ 2\\ \underline{3}\end{array}\right\}$$

CAMERA = 2

Option	Meaning
FILM or 1	35 mm or 16 mm film (positive or negative images).
PAPER or 2	Positive prints.
BØTH or 3	Positive prints and 35 mm or 16 mm film.

Remarks: 1. This card is optional. It pertains to all types of plots (whole frame, upper half frame and lower half frame).

X-Y Output Data Card <u>CLEAR</u> - Parameter Default Value Restoration

Description: Causes all parameter values except those defined by the PLØTTER card and the titles defined by XTITLE, YTITLE, YTTITLE, YBTITLE and TCURVE to revert to their default values.

Format:

CLEAR

Remarks:
1. This card is optional. It pertains to all types of plots (whole frame, upper half frame and lower half frame).
2. The user must be very careful in the use of this card because of its impact on all parameters except those mentioned in the description above.

X-Y Output Data Card CSCALE - Character Scale Specification

Description: Specifies the scale to be used for alphanumeric characters in an X-Y plot.

Format and Example:

CSCALE = $\begin{Bmatrix} n \\ \underline{1} \end{Bmatrix}$

CSCALE = 2

Option	Meaning
n	Factor by which the normal (or default) size of alphanumeric characters is multiplied (Integer > 0).

Remarks:

1. This card is optional. It pertains to all types of plots (whole frame, upper half frame and lower half frame).
2. See Section 4.1.1 for an important discussion on plot frame size and character size.

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X-Y Output Data Card CURVELINESYMBØL - Curve Line and Symbol Selection

Description: Specifies whether the points on a curve should be connected by lines, identified by symbols or both.

Format and Example:

CURVELINESYMBØL = n

CURVELINESYMBØL = 1

Option	Meaning	
n	Integer value ($-9 \leq n \geq 9$) with the following meanings:	
	$-9 \leq n < 0$	Points on a curve to be identified by symbols as per the table below. See also Remark 2.
	$n = 0$ (default)	Points on a curve to be connected by lines.
	$0 < n \leq 9$	Points on a curve to be connected by lines as well as identified by symbols as per the table below. See also Remark 2.

Remarks:

1. This card is optional. It pertains to all types of plots (whole frame, upper half frame and lower half frame).
2. If $n \neq 0$, the first curve on a frame will be identified by the symbol corresponding to n. Subsequent curves on the same frame will cause n to be incremented (if $n > 0$) or decremented (if $n < 0$) by one for each curve and thus cycle thr ugh the available symbols.
3. The following table gives the correspondence between the values of n and the symbols used for identifying the points on a curve.

n	Symbol
0	no symbol
1	X
2	*
3	+
4	-
5	•
6	O
7	□
8	◊
9	Δ

X-Y Output Data Card DENSITY - Line Density

Description: Specifies line density for microfilm plotters.

Format and Example:

$$\text{DENSITY} = \begin{Bmatrix} d \\ \underline{1} \end{Bmatrix}$$

DENSITY = 3

Option	Meaning
d	Line density (Integer > 0). A line density of d is d times heavier than a line density of 1.

Remarks: 1. This card is optional. It pertains to all types of plots (whole frame, upper half frame and lower half frame).

X-Y Output Data Card LEFT TICS - Left Edge Tic Request

Description: Requests use of tic marks on the left edge of whole frame plots only.

Format and Example:

LEFT TICS = $\begin{Bmatrix} -1 \\ 0 \\ \underline{1} \end{Bmatrix}$

LEFT TICS = 0

Option	Meaning
-1	Draw tic marks without values on the left edge. See Remark 2 below.
0	Do not draw either tic marks or values on the left edge. See Remark 2 below.
1	Draw tic marks with values on the left edge. See Remark 2 below.

Remarks:

1. This card is optional. It pertains only to whole frame plots.
2. The above meanings for the options may be altered when ALLEDGE TICS card is also used. See Section 4.3.2.2 for details.

X-Y Output Data Card LØWER TICS - Lower Edge Tic Request

Description: Requests use of tic marks on the lower edge of a frame.

Format and Example:

LØWER TICS = $\left\{\begin{matrix} -1 \\ 0 \\ \underline{1} \end{matrix}\right\}$

LØWER TICS = 0

Option	Meaning
-1	Draw tic marks without values on the lower edge. See Remark 2 below.
0	Do not draw either tic marks or values on the lower edge. See Remark 2 below.
1	Draw tic marks with values on the lower edge. See Remark 2 below.

Remarks:

1. This card is optional. It pertains to all types of plots (whole frame, lower half frame and bottom half frame).

2. The above meanings for the options may be altered when ALLEDGE TICS, TALL EDGE TICS or BALL EDGE TICS are used. See Section 4.3.2.2 for details.

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X-Y Output Data Card PENSIZE - Pen Specification

Description: Specifies the size of the pen to be used for plotting on table and drum plotters.

Format and Example:

$$\text{PENSIZE} = \begin{Bmatrix} n \\ \underline{1} \end{Bmatrix}$$

PENSIZE = 2

Option	Meaning
n	Size of the pen to be used for plotting on table and drum plotters (Integer > 0).

Remarks: 1. This card is optional. It pertains to all types of plots (whole frame, upper half frame and lower half frame).

X-Y Output Data Card PLØTTER - Plotter Model Specification

Description: Specifies the model and the typing capability of the plotter to be used for plotting.

Format and Example:

$$\text{PLØTTER = NASTPLT} \quad , \text{[MØDEL]} \begin{Bmatrix} \underline{M} \\ T \\ D \end{Bmatrix} , \begin{Bmatrix} 0 \\ \underline{1} \end{Bmatrix}$$

PLØTTER = NASTPLT, T, 0

Option	Meaning
M	Microfilm plotter.
T	Table plotter.
D	Drum plotter.
0	Plotter has typing capability.
1	Plotter has no typing capability. In this case, all characters will be drawn.

Remarks:

1. This card is optional. If it is used, it is recommended that it be the very first card after the ØUTPUT(XYØUT) or ØUTPUT(XYPLØT) card in the X-Y output request packet.

2. This card pertains to all types of plots (whole frame, upper half frame and lower half frame).

X-Y Output Data Card RIGHT TICS - Right Edge Tic Request

Description: Requests use of tic marks on the right edge of whole frame plots only.

Format and Example:

RIGHT TICS = $\begin{Bmatrix} -1 \\ 0 \\ \underline{1} \end{Bmatrix}$

RIGHT TICS = 0

Option	Meaning
-1	Draw tic marks without values on the right edge. See Remark 2 below.
0	Do not draw either tic marks or values on the right edge. See Remark 2 below.
1	Draw tic marks with values on the right edge. See Remark 2 below.

Remarks:
1. This card is optional. It pertains only to whole frame plots.
2. The above meanings for the options may be altered when ALLEDGE TICS card is also used. See Section 4.3.2.2 for details.

X-Y Output Data Card SKIP - Blank Frame Insertion Specification

Description: Specifies the number of blank frames to be inserted between requested frames for microfilm plotters.

Format and Example:

$$\text{SKIP} = \begin{Bmatrix} n \\ \underline{1} \end{Bmatrix}$$

SKIP = 2

Option	Meaning
n	Number of blank frames to be inserted (Integer > 0).

Remarks: 1. This card is optional. It pertains to all types of plots (whole frame, upper half frame and lower half frame).

X-Y Output Data Card TALL EDGE TICS - All Edge Tic Request

Description: Requests use of tic marks on all edges of upper half frame plots only.

Format and Example:

$$\text{TALLEDGE TICS} = \begin{Bmatrix} -1 \\ 0 \\ \underline{1} \end{Bmatrix}$$

TALLEDGE TICS = 0

Option	Meaning
-1	Draw tic marks without values on all edges. See Remark 2 below.
0	Do not draw either tic marks or values on any edge. See Remark 2 below.
1	Draw tic marks with values on all edges. See Remark 2 below.

Remarks:

1. This card is optional. It pertains only to upper half frame plots.
2. When this card is used, the effects of other "TICS" cards may be altered. See Section 4.3.2.2 for details.

X-Y Output Data Card TCURVE - Curve Title

Description: Specifies the title for a curve.

Format and Example:

TCURVE = title

TCURVE = TRANSIENT RESPONSE

Option	Meaning
title	Any BCD string to be used as the title for a curve.

Remarks: 1. This card is optional. It pertains to all types of plots (whole frame, upper half frame and lower half frame).

2. The data for this card must be specified on only one physical card.

X-Y Output Data Card TLEFT TICS - Left Edge Tic Request

Description: Requests use of tic marks on the left edge of upper half frame plots only.

Format and Example:

$$\text{TLEFT TICS} = \begin{Bmatrix} -1 \\ 0 \\ \underline{1} \end{Bmatrix}$$

TLEFT TICS = 0

Option	Meaning
-1	Draw tic marks without values on the left edge. See Remark 2 below.
0	Do not draw either tic marks or values on the left edge. See Remark 2 below.
1	Draw tic marks with values on the left edge. See Remark 2 below.

Remarks:

1. This card is optional. It pertains only to upper half frame plots.
2. The above meanings for the options may be altered when TALLEDGE TICS card is also used. See Section 4.3.2.2 for details.

X-Y Output Data Card TRIGHT TICS - Right Edge Tic Request

Description: Requests use of tic marks on the right edge of upper half frame plots only.

Format and Example:

$$\text{TRIGHT TICS} = \left\{\begin{matrix} -1 \\ 0 \\ \underline{1} \end{matrix}\right\}$$

TRIGHT TICS = 0

Option	Meaning
-1	Draw tic marks without values on the right edge. See Remark 2 below.
0	Do not draw either tic marks or values on the right edge. See Remark 2 below.
1	Draw tic marks with values on the right edge. See Remark 2 below.

Remarks:
1. This card is optional. It pertains only to upper half frame plots.
2. The above meanings for the options may be altered when TALL EDGE TICS card is also used. See Section 4.3.2.2 for details.

X-Y Output Data Card UPPER TICS - Upper Edge Tic Request

Description: Requests use of tic marks on the upper edge of a frame.

Format and Example:

$$\text{UPPER TICS} = \begin{Bmatrix} -1 \\ 0 \\ \underline{1} \end{Bmatrix}$$

UPPER TICS = 0

Option	Meaning
-1	Draw tic marks without values on the upper edge. See Remark 2 below.
0	Do not draw either tic marks or values on the upper edge. See Remark 2 below.
1	Draw tic marks with values on the upper edge. See Remark 2 below.

Remarks:

1. This card is optional. It pertains to all types of plots (whole frame, upper half frame and bottom half frame).
2. The above meanings for the options may be altered when ALLEDGE TICS, TALL EDGE TICS or BALL EDGE TICS are used. See Section 4.3.2.2 for details.

X-Y Output Data Card XAXIS - X-axis Plot Request

Description: Requests plotting of X-axis on whole frame plots only.

Format and Example:

$$\text{XAXIS} = \begin{Bmatrix} \text{YES} \\ \underline{\text{NØ}} \end{Bmatrix}$$

XAXIS = YES

Option	Meaning
YES	Plot X-axis.
NØ	Do not plot X-axis.

Remarks: 1. This card is optional. It pertains only to whole frame plots.

X-Y Output Data Card XBAXIS - X-axis Plot Request

Description: Requests plotting of X-axis on lower half frame plots only.

Format and Example:

XBAXIS = $\begin{Bmatrix} \text{YES} \\ \underline{\text{NØ}} \end{Bmatrix}$

XBAXIS = YES

Option	Meaning
YES	Plot X-axis.
NØ	Do not plot X-axis.

Remarks: 1. This card is optional. It pertains only to lower half frame plots.

X-Y Output Data Card XBGRID LINES - X-grid Lines Request

Description: Requests the drawing of grid lines parallel to the X-axis on lower half frame plots only.

Format and Example:

XBGRID LINES = {YES / NØ}

XBGRID LINES = YES

Option	Meaning
YES	Draw grid lines parallel to the X-axis at locations requested for tic marks.
NØ	Do not draw grid lines parallel to the X-axis.

Remarks: 1. This card is optional. It pertains only to lower half frame plots.

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X-Y Output Data Card XDIVISIØNS - X-direction Spacing

Description: Specifies the spacing to be used along the X-direction for non-log scales.

Format and Example:

XDIVISIONS = $\begin{Bmatrix} n \\ \underline{5} \end{Bmatrix}$

XDIVISIONS = 4

Option	Meaning
n	Number of uniform spaces to be used along the X-direction for whichever of the following are called for: XAXIS, UPPER TICS, LØWER TICS (Integer > 0). Applicable only to non-log scales.

Remarks: 1. This card is optional. It pertains to all types of plots (whole frame, upper half frame and lower half frame).

X-Y Output Data Card XGRID LINES - X-grid Lines Request

Description: Requests the drawing of grid lines parallel to the X-axis on whole frame plots only.

Format and Example:

XGRID LINES = {YES / NØ}

XGRID LINES = YES

Option	Meaning
YES	Draw grid lines parallel to the X-axis at locations requested for tic marks.
NØ	Do not draw grid lines parallel to the X-axis.

Remarks: 1. This card is optional. It pertains only to whole frame plots.

X-Y Output Data Card XINTERCEPT - Y-axis Position

Description: Specifies the location on the X-axis where the Y-axis will be drawn.

Format and Example:

XINTERCEPT = $\left\{\begin{matrix} x_c \\ \underline{0.0} \end{matrix}\right\}$

XINTERCEPT = 1.0

Option	Meaning
x_c	Y-axis will have its x-coordinate = x_c (Real).

Remarks: 1. This card is optional. It applies to all types of plots (whole frame, upper half frame and lower half frame).

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X-Y Output Data Card XLØG - Logarithmic X-coordinate Request

Description: Requests logarithmic scale for X-coordinates.

Format and Example:

XLØG = {YES, NØ}

XLØG = YES

Option	Meaning
YES	Use logarithmic scale for X-coordinates.
NØ	Use linear scale for X-coordinates.

Remarks:

1. This card is optional. It pertains to all types of plots (whole frame, upper half frame and lower half frame).
2. The default values for tic divisions on log plots are as follows, but range over whole cycles:

Number of Cycles	Intermediate Values
1, 2	2., 3., 4., 5., 6., 7., 8., 9.
3	2., 3., 5., 7., 9.
4	2., 4., 6., 8.
5	2., 5., 8.
6, 7	3., 6.
8, 9, 10	3.

X-Y Output Data Card XMAX - Upper Limit of Abscissa

Description: Specifies the upper limit of the abscissa of a curve.

Format and Example:

XMAX = x

XMAX = 10.0

Option	Meaning
x	Upper limit of the abscissa (Real).

Remarks:

1. This card is optional. It pertains to all types of plots (whole frame, upper half frame and lower half frame).
2. If this card is not used, the default value is chosen so as to accommodate all points.

X-Y Output Data Card XMIN - Lower Limit of Abscissa

Description: Specifies the lower limit of the abscissa of a curve.

Format and Example:

XMIN = x

XMIN = 1.0

Option	Meaning
x	Lower limit of the abscissa (Real).

Remarks:

1. This card is optional. It pertains to all types of plots (whole frame, upper half frame and lower half frame).
2. If this card is not used, the default value is chosen so as to accommodate all points.

X-Y Output Data Card XPAPER - Plot Frame X-dimension

Description: Specifies the X-dimension of the plot frame (x by y) for table and drum plotters. (For microfilm plotters, the plot frame size is set at 10.23 inches x 10.23 inches and is not under user control.)

Format and Example:

XPAPER = x

XPAPER = 15.0

Option	Meaning
x	X-dimension of the plot frame in inches (Real > 0.0). Must not exceed 30.0 for table plotters.

Remarks:

1. This card is optional. It pertains to all types of plots (whole frame, upper half frame or lower half frame).
2. If this card is not used, the following default values are used:

Plotter model	Default value for x (inches)
Table	11.0
Drum	30.0

3. See Section 4.1.1 for an important discussion on plot frame size and character size.

X-Y Output Data Card XTAXIS - X-axis Plot Request

Description: Requests plotting of X-axis on upper half frame plots only.

Format and Example:

$$XTAXIS = \begin{Bmatrix} YES \\ \underline{NØ} \end{Bmatrix}$$

XTAXIS = YES

Option	Meaning
YES	Plot X-axis.
NØ	Do not plot X-axis.

Remarks: 1. This card is optional. It pertains only to upper half frame plots.

X-Y Output Data Card XTGRID LINES - X-grid Lines Request

Description: Requests the drawing of grid lines parallel to the X-axis on upper half frame plots only.

Format and Example:

XTGRID LINES = $\begin{Bmatrix} \text{YES} \\ \underline{\text{NØ}} \end{Bmatrix}$

XTGRID LINES = YES

Option	Meaning
YES	Draw grid lines parallel to the X-axis at locations requested for tic marks.
NØ	Do not draw grid lines parallel to the X-axis.

Remarks: 1. This card is optional. It pertains only to upper half frame plots.

X-Y Output Data Card <u>XTITLE</u> - X-axis Title

<u>Description</u>: Specifies the title for the X-axis.

<u>Format and Example</u>:

XTITLE = title

XTITLE = TIME (SEC.)

<u>Option</u>	<u>Meaning</u>
title	Any BCD string to be used as the title for the X-axis.

<u>Remarks</u>:

1. This card is optional. It pertains to <u>all types of plots</u> (whole frame, upper half frame and lower half frame).

2. The data for this card must be specified on only <u>one</u> physical card.

X-Y Output Data Card XVALUE PRINT SKIP - X-tic Skip Specification

Description: Specifies the number of tic marks to be skipped between labeled tic marks on the X-axis.

Format and Example:

XVALUE PRINT SKIP = $\begin{Bmatrix} n \\ \underline{0} \end{Bmatrix}$

XVALUE PRINT SKIP = 1

Option	Meaning
n	Number of tic marks to skipped between labeled tic marks on the X-axis (Integer ≥ 0). Thus, every $(n + 1)^{th}$ tic mark on the X-axis will be labeled.

Remarks: 1. This card is optional. It pertains to all types of plots (whole frame, upper half frame and lower half frame).

X-Y Output Data Card XYPAPLØT - X-Y Paper Plot Command

Description: Causes generation of X-Y plots within the printed output.

Note: For the sake of convenience and completeness, this card and all other X-Y command operation cards are described together under the description of the XYPLØT command operation card. Please refer to that card for details.

X-Y Output Data Card XYPEAK - X-Y Summary Command

Description: Causes generation of printed summary page for each curve.

Note: For the sake of convenience and completeness, this card and all other X-Y command operation cards are described together under the description of the XYPLØT command operation card. Please refer to that card for details.

X-Y Output Data Card XYPLØT - X-Y Plot Command

Description: Causes generation of X-Y plots for the selected plotter.

Note: For the sake of convenience and completeness, the XYPLØT card is described below in conjunction with all of the other X-Y command operation cards (XYPRINT, XYPUNCH, XYPEAK and XYPAPLØT cards).

Format:

Operation 1 or more (required)	Curve Type 1 only (required)	Plot Type	Subcase List	Curve Request(s) (required)
XYPLØT XYPRINT XYPUNCH XYPEAK XYPAPLØT	ACCE DISP ELFØRCE ELSTRESS FØRCE LØAD NØNLINEAR ØLØAD SACCE SDISP SPCF STRESS SVELØ VECTØR VELØ VG	RESPØNSE AUTØ PSDF	i_1, i_2, i_3, i_4 THRU i_5, i_6, etc. default is all subcases	"frames"

Option — Meaning

Operation

XYPLØT — Generate one or more frames of X-Y plots on the selected plotter using the current parameter specifications.

XYPRINT — Generate tabular printer output for the X-Y pairs. See also Remark 2.

XYPUNCH — Generate punched card output for the X-Y pairs. Each card contains the following information:

1. X-Y pair sequence number
2. X-value
3. Y-value
4. Card sequence number

XYPEAK — Output is limited to the printed summary page for each curve. This summary page contains the maximum and minimum values of y for the range of x.

(Continued)

XYPLØT (Cont.)

XYPAPLØT	Generate X-Y plots within the printed output. This is a capability to provide minimum output for the purpose of observing general curve behavior. Many of the detailed specifications described elsewhere in this section are not supported. This feature is limited to producing Cartesian plots with titles, overall scales and data point locations. When the paper is rotated 90° for viewing the paper plots, the X-axis moves horizontally along the page and the Y-axis moves vertically along the page. Symbol "*" identifies the points associated with the first curve of a frame, then for successive curves on the same frame, the points are designated by the symbols "O", "A", "B", "C", "D", "E", "F", "G" and "H".

Curve Type

ACCE	Acceleration in the physical set
DISP	Displacement in the physical set
ELFØRCE	Element force
ELSTRESS	Element stress
FØRCE	Element force (same as ELFØRCE)
LØAD	Load
NØNLINEAR	Nonlinear load
ØLØAD	Load (same as LØAD)
SACCE	Acceleration in the solution set
SDISP	Displacement in the solution set
SPCF	Single-point force of constraint
STRESS	Element stress (same as ELSTRESS)
SVELØ	Velocity in the solution set
VECTØR	Displacement in the physical set (same as DISP)
VELØ	Velocity in the physical set
VG	Flutter analysis curves

Solution set requests are more efficient, as the time-consuming recovery of the dependent displacements can be avoided. However, if there is a request for ELSTRESS (or STRESS) or ELFØRCE (or FØRCE), the recovery of dependent displacements cannot be avoided.

Plot Type

RESPØNSE	Generate output for static analysis, frequency response or transient response. This is the default value.
AUTØ	Generate output for the autocorrelation function.
PSDF	Generate output for the power spectral density function.

(Continued)

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Subcase List

$i_1, i_2, i_3, i_4, i_5, i_6$ etc. — Generate output for the subcase numbers that are listed. The subcase list must be in ascending order. The default is all subcases for which solutions were obtained.

Curve Request(s)

"frames" — The word "frames" represents a series of curve identifiers of the following general form:

/a1(b1,c1),a2(b2,c2),etc./d1(e1,f1),d2(e2,f2),etc./etc.

The information following each slash (/) specifies curves that are to be drawn on the same frame. For all plots except the VG plot, the symbol a1 identifies the grid point or element number associated with the first curve on the first frame. The symbol a2 identifies the grid point or element number associated with the second curve on the first frame. The symbols d1 and d2 identify similar items for curves on the second frame, etc. For any particular frame, the symbols must be assigned in ascending order by grid point or element identification number and item code. For VG plots, the symbols a1, a2 etc., refer to the loop count of the flutter analysis.

The symbols b1 and b2 are codes for the components to be plotted on the upper half of the first frame, and c1 and c2 are codes for the components to be plotted on the lower half of the first frame. If any of the symbols b1, c1, b2 or c2 are missing, the corresponding curve is not generated. If the comma (,) and c1 are absent along with the comma (,) and c2, full frame plots will be prepared on the first frame for the components represented by b1 and b2. For any single frame, curve identifiers must be all of the whole frame type or all of the half frame type, i.e., the comma (,) following b1 and b2 must be present for all entries or absent for all entries in a single frame. The symbols e1, f1, e2 and f2 serve a similar purpose for the second frame, etc. If continuation cards are needed, the previous card must be terminated either with a slash (/) or a comma (,) as indicated in Section 4.3.2.4.

For VG plots, the component codes (b1, b2, etc. and c1, c2, etc.) may have the values F (for frequency) or G (for damping). For all other plots, the manner in which the component code is implemented is dependent upon whether the plot type is (a) RESPØNSE or (b) AUTØ or PSDF. This is described below.

Component Codes for Plot Type RESPØNSE

For geometric grid points, the component code is one of the mnemonics T1, T2, T3, R1, R2, R3, T1RM, T2RM, T3RM, R1RM, R2RM, R3RM, T1IP, T2IP, T3IP, R1IP, R2IP or R3IP, where Ti stands for the i^{th} translational component, Ri stands for the i^{th} rotational component, and RM means real or magnitude and IP means imaginary or phase. For scalar or extra points, use T1, T1RM or T1IP. (See Remark 2 below for the interpretation of component codes for geometric grid, scalar and extra points in the printed X-Y output). For elements, use a positive integer from the following tables for element stress component codes (Table 2) or element force component codes (Table 3). (See Section 1.3 for the interpretation of the symbols used in Tables 2 and 3 for element stress and force components).

(Continued)

XYPLØT (Cont.)

Component Codes for Plot Type AUTØ or PSDF

For geometric grid points, the component code is one of the mnemonics T1, T2, T3, R1, R2 or R3; for scalar or extra points use T1. The symbols T1, T2, T3, R1, R2 and R3 are defined as above. (See Remark 2 below for the interpretation of component codes for geometric grid, scalar and extra points in the printed X-Y output). For elements, use a positive integer from the following tables noting that if a component has a real and an imaginary part, the selection of either part will result in the use of both the parts. Real numbers in the output will be treated as if they are complex numbers with zero imaginary parts. Split frames cannot be used for AUTØ or PSDF plots.

Remarks:

1. At least one command operation card (XYPLØT, XYPRINT, XYPUNCH, XYPEAK or XYPAPLØT) must appear in an X-Y output packet request.

2. In the printed X-Y output, the component codes shown for the geometric grid, scalar or extra points are not the same as the mnemonics input on the command operation cards. Instead, the component codes are identified by integers as indicated by the following table.

Component Code Identification for Geometric Grid,

Scalar and Extra Points in Printed X-Y Output

Component code specified on the command operation card	Component code shown in the printed X-Y Output
T1 or T1RM	1
T2 or T2RM	2
T3 or T3RM	3
R1 or R1RM	4
R2 or R2RM	5
R3 or R3RM	6
T1IP	7
T2IP	8
T3IP	9
T4IP	10
T5IP	11
T6IP	12

Examples:

Following are some examples illustrating the use of X-Y output command operation cards. The BEGIN BULK or ØUTPUT(PLØT) card is shown as a reminder to the user to place his X-Y output request packet properly in his Case Control Deck, i.e., at the end of the Case Control Deck or just ahead of any structure plot requests. The user must ensure that file PLT2 is set up for plotting use via system control cards to use a tape or mass storage area.

(Continued)

XYPLØT (Cont.)

Example 1

```
ØUTPUT(XYPLØT)
XYPLØT SDISP / 16(T1)
BEGIN BULK
```

Causes a single whole frame to be plotted for the T1 displacement component of solution set point 16 using the default parameter values. If 16(T1) is not in the solution set, a warning message will be printed and no plot will be made. Since there is no PLØTTER card, the plot will be generated, by default, for a microfilm plotter without typing capability.

Example 2

```
ØUTPUT(XYØUT)
PLØTTER = NASTPLT D, 1
XYPLØT, XYPRINT VELØ RESPØNSE 1,5 / 3(R1, ), 5( ,R1)
```

Causes a single frame (consisting of an upper half frame and a lower half frame) to be plotted using the default parameter values. The velocity of the first rotational component of grid point 3 will be plotted on the upper half frame and that of grid point 5 will be plotted on the lower half frame for subcases 1 and 5. Tabular printer output will also be generated for both curves. The plots will be generated for a drum plotter without typing capability. Scales will be selected such that the frame will fit on 30 x 30-inch paper.

Example 3

```
ØUTPUT(XYPLØT)
PLØTTER = NASTPLT T, 0
YDIVISIØNS = 20
XDIVISIØNS = 10
XGRID LINES = YES
YGRID LINES = YES
XYPLØT DISP 2,5 /10(T1),10(T3)
```

Causes two whole frame plots to be generated, one for subcase 2 and one for subcase 5. Each plot contains the T1 and T3 displacement components for grid point 10. The default parameters will be modified to include grid lines in both the X- and Y-directions with 10 spaces in the X-direction and 20 spaces in the Y-direction. The plot will be generated for a table plotter with typing capability.

Example 4

```
ØUTPUT(XYPLØT)
PLØTTER = NASTPLT T, 1
XAXIS = YES
YAXIS = YES
```

(Continued)

XYPLØT (Cont.)


```
XPAPER = 17.0
YPAPER = 22.0
XYPLØT STRESS 3/ 15(2)/ 21(6)
```

Causes two whole frame plots to be generated using the results from subcase 3. The first plot is the response of the axial stress for rod (RØD) element number 15. The second plot is the response of the major principal stress for triangular membrane (TRMEM) element number 21. The default parameters will be modified to include the X-axis and Y-axis drawn through the origin. Each plot will be scaled to fit on 17 x 22 inch paper. The plots will be generated for a table plotter without typing capability.

Example 5

```
ØUTPUT(XYPLØT)
PLØTTER = NASTPLT D,0
CURVELINESYMBØL = -1
XYPLØT VG / 1(G,F), 2(G,F), 3(G,F), 4(G,F)
```

A split frame plot will be made; the upper half is V-g and the lower half is V-f. Data from the first four loops will be plotted. Distinct symbols will be used for data from each loop, and no lines will be drawn between points (since the flutter analyst must sometimes exercise judgement about which points should be connected). The plots will be generated for a drum plotter with typing capability.

Table 2. Element Stress Component Codes for Use on X-Y Output Command Operation Cards

(All components are stresses unless otherwise denoted)

Element Name	Real Element Stresses		Complex Element Stresses		
	Component Code	Component	Component Code	Component	Real-Mag. or Imag.-Phase
AXIF2	2	Radial-Axis	2	Radial-Axis	RM
	3	Axial-Axis	3	Axial-Axis	RM
	4	Tangential-Edge	4	Tangential-Edge	RM
	5	Circumferential-Edge	5	Circumferential-Edge	RM
			6	Radial-Axis	IP
			7	Axial-Axis	IP
			8	Tangential-Edge	IP
			9	Circumferential-Edge	IP
AXIF3	2	Radial-centroid	2	Radial-centroid	RM
	3	Circumferential-centroid	3	Circumferential-centroid	RM
	4	Axial-centroid	4	Axial-centroid	RM
	5	Tangential-edge 1	5	Tangential-edge 1	RM
	6	Circumferential-edge 1	6	Circumferential-edge 1	RM
	7	Tangential-edge 2	7	Tangential-edge 2	RM
	8	Circumferential-edge 2	8	Circumferential-edge 2	RM
	9	Tangential-edge 3	9	Tangential-edge 3	RM
	10	Circumferential-edge 3	10	Circumferential-edge 3	RM
			11	Radial-centroid	IP
			12	Circumferential-centroid	IP
			13	Axial-centroid	IP
			14	Tangential-edge 1	IP
			15	Circumferential-edge 1	IP
			16	Tangential-edge 2	IP
			17	Circumferential-edge 2	IP
			18	Tangential-edge 3	IP
			19	Circumferential-edge 3	IP
AXIF4	2	Radial-centroid	2	Radial-centroid	RM
	3	Circumferential-centroid	3	Circumferential-centroid	RM
	4	Axial-centroid	4	Axial-centroid	RM
	5	Tangential-edge 1	5	Tangential-edge 1	RM
	6	Circumferential-edge 1	6	Circumferential-edge 1	RM
	7	Tangential-edge 2	7	Tangential-edge 2	RM
	8	Circumferential-edge 2	8	Circumferential-edge 2	RM
	9	Tangential-edge 3	9	Tangential-edge 3	RM
	10	Circumferential-edge 3	10	Circumferential-edge 3	RM
	11	Tangential-edge 4	11	Tangential-edge 4	RM
	12	Circumferential-edge 4	12	Circumferential-edge 4	RM
			13	Radial-centroid	IP
			14	Circumferential-centroid	IP
			15	Axial-centroid	IP
			16	Tangential-edge 1	IP
			17	Circumferential-edge 1	IP
			18	Tangential-edge 2	IP
			19	Circumferential-edge 2	IP
			20	Tangential-edge 3	IP
			21	Circumferential-edge 3	IP
			22	Tangential-edge 4	IP
			23	Circumferential-edge 4	IP

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Table 2. Element Stress Component Codes for Use on X-Y Output Command Operation Cards (continued)

(All components are stresses unless otherwise denoted)

Element Name	Real Element Stresses		Complex Element Stresses		
	Component Code	Component	Component Code	Component	Real-Mag. or Imag.-Phase
BAR	2	SA1	2	SA1	RM
	3	SA2 *	3	SA2 *	RM
	4	SA3	4	SA3	RM
	5	SA4	5	SA4	RM
	6	Axial	6	Axial	RM
	7	SA-maximum	7	SA1	IP
	8	SA-minimum	8	SA2 *	IP
	9	Safety Margin in Tension	9	SA3	IP
	10	SB1	10	SA4	IP
	11	SB2 *	11	Axial	IP
	12	SB3	12	SB1	RM
	13	SB4	13	SB2	RM
	14	SB-maximum	14	SB3	RM
	15	SB-minimum	15	SB4 *	RM
	16	Safety Margin in Comp.	16	SB1	IP
			17	SB2	IP
			18	SB3	IP
			19	SB4	IP
CØNEAX		Z1 = Fibre Distance 1			
	4	Normal-u at 1			
	5	Normal-v at 1			
	6	Shear-uv at 1			
	7	θ-Shear Angle at 1			
	8	Major-Principal at 1			
	9	Minor-Principal at 1			
	10	Maximum Shear at 1			
		Z2 = Fibre Distance 2			
	12	Normal-u at 2			
	13	Normal-v at 2			
	14	Shear-uv at 2			
	15	θ-Shear Angle at 2			
	16	Major-Principal at 2			
	17	Minor-Principal at 2			
	18	Maximum Shear at 2			
CØNRØD		Same as RØD		Same as RØD	
ELAS1	2	Stress	2	Stress	RM
			3	Stress	IP
ELAS2	2	Stress	2	Stress	RM
			3	Stress	IP
ELAS3	2	Stress	2	Stress	RM
			3	Stress	IP

*See Note 2 at the end of this table.

(Continued)

Table 2. Element Stress Component Codes for Use on X-Y Output Command Operation Cards (continued)

(All components are stresses unless otherwise denoted)

	Real Element Stresses		Complex Element Stresses		
Element Name	Component Code	Component	Component Code	Component	Real-Mag. or Imag.-Phase
HEXA1		Same as TETRA		Same as TETRA	
HEXA2		Same as TETRA		Same as TETRA	
IHEX1*	2	External grid point ID	2	External grid point ID	
	3	Normal-x	3	Normal-x	RM
	4	Shear-xy	4	Normal-y	RM
	5	First principal	5	Normal-z	RM
	6	First principal x cosine	6	Shear-xy	RM
	7	Second principal x cosine	7	Shear-yz	RM
	8	Third principal x cosine	8	Shear-zx	RM
	9	Mean stress	9	Normal-x	IP
	10	Octahedral shear stress	10	Normal-y	IP
	11	Normal-y	11	Normal-z	IP
	12	Shear-yz	12	Shear-xy	IP
	13	Second principal	13	Shear-yz	IP
	14	First principal y cosine	14	Shear-zx	IP
	15	Second principal y cosine			
	16	Third principal y cosine			
	17	Normal-z			
	18	Shear-zx			
	19	Third principal			
	20	First principal z cosine			
	21	Second principal z cosine			
	22	Third principal z cosine			
IHEX2*		Same as IHEX1		Same as IHEX1	
IHEX3*	2	First external grid point ID	2	First external grid point ID	
	3	Normal-x	3	Normal-x	RM
	4	Shear-xy	4	Normal-y	RM
	5	First principal	5	Normal-z	RM
	6	First principal x cosine	6	Shear-xy	RM
	7	Second principal x cosine	7	Shear-yz	RM
	8	Third principal x cosine	8	Shear-zx	RM
	9	Mean Stress	9	Second external grid point ID	
	10	Octahedral shear stress	10	Normal-x	IP
	11	Second external grid point ID	11	Normal-y	IP
	12	Normal-y	12	Normal-z	IP
	13	Shear-yz	13	Shear-xy	IP
	14	Second principal	14	Shear-yz	IP
	15	First principal y cosine	15	Shear-zx	IP
	16	Second principal y cosine			
	17	Third principal y cosine			

*The stresses are repeated for each stress point within each element.

(Continued)

Table 2. Element Stress Component Codes for Use on X-Y Output Command Operation Cards (continued)

(All components are stresses unless otherwise denoted)

Element Name	Real Element Stresses		Complex Element Stresses		
	Component Code	Component	Component Code	Component	Real-Mag. or Imag.-Phase
IHEX3 (cont.)	18	Normal-z			
	19	Shear-zx			
	20	Third principal			
	21	First principal z cosine			
	22	Second principal z cosine			
	23	Third principal z cosine			
QDMEM		Same as TRMEM		Same as TRMEM	
QDMEM1		Same as TRMEM		Same as TRMEM	
QDMEM2		Same as TRMEM		Same as TRMEM	
QDPLT		Same as TRIA1		Same as TRIA1	
QUAD1		Same as TRIA1		Same as TRIA1	
QUAD2		Same as TRIA1		Same as TRIA1	
RØD	2	Axial Stress	2	Axial Stress	RM
	3	Axial Safety Margin	3	Axial Stress	IP
	4	Torsional Stress	4	Torsional Stress	RM
	5	Torsional Safety Margin	5	Torsional Stress	IP
SHEAR	2	Maximum Shear	2	Maximum Shear	RM
	3	Average Shear	3	Maximum Shear	IP
	4	Safety Margin	4	Average Shear	RM
			5	Average Shear	IP
SLØT3	2	Radial-centroid	2	Radial-centroid	RM
	3	Axial-centroid	3	Axial-centroid	RM
	4	Tangential-edge 1	4	Tangential-edge 1	RM
	5	Tangential-edge 2	5	Tangential-edge 2	RM
	6	Tangential-edge 3	6	Tangential-edge 3	RM
			7	Radial-centroid	IP
			8	Axial-centroid	IP
			9	Tangential-edge 1	IP
			10	Tangential-edge 2	IP
			11	Tangential-edge 3	IP
SLØT4	2	Radial-centroid	2	Radial-centroid	RM
	3	Axial-centroid	3	Axial-centroid	RM
	4	Tangential-edge 1	4	Tangential-edge 1	RM
	5	Tangential-edge 2	5	Tangential-edge 2	RM
	6	Tangential-edge 3	6	Tangential-edge 3	RM
	7	Tangential-edge 4	7	Tangential-edge 4	RM
			8	Radial-centroid	IP
			9	Axial-centroid	IP

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Table 2. Element Stress Component Codes for Use on X-Y Output Command Operation Cards (continued)

(All components are stresses unless otherwise denoted)

	Real Element Stresses		Complex Element Stresses		
Element Name	Component Code	Component	Component Code	Component	Real-Mag. or Imag.-Phase
SLØT4 (cont.)			10	Tangential-edge 1	IP
			11	Tangential-edge 2	IP
			12	Tangential-edge 3	IP
			13	Tangential-edge 4	IP
TETRA	2	Normal (x)	2	Normal (x)	RM
	3	Normal (y)	3	Normal (y)	RM
	4	Normal (z)	4	Normal (z)	RM
	5	Shear (yz)	5	Shear (yz)	RM
	6	Shear (xy)	6	Shear (xy)	RM
	7	Shear (xz)	7	Shear (xz)	RM
	8	Octahedral	8	Normal (x)	IP
	9	Pressure	9	Normal (y)	IP
			10	Normal (z)	IP
			11	Shear (yz)	IP
			12	Shear (xy)	IP
			13	Shear (xz)	IP
TØRDRG	2	Mem.-Tangen. at 1			
	3	Mem.-Circum. at 1			
	4	Flex.-Tangen. at 1			
	5	Flex.-Circum. at 1			
	6	Shear-Force at 1			
	7	Mem.-Tangen. at 2			
	8	Mem.-Circum. at 2			
	9	Flex.-Tangen. at 2			
	10	Flex.-Circum. at 2			
	11	Shear-Force at 2			
	12	Mem.-Tangen. at 3			
	13	Mem.-Circum. at 3			
	14	Flex.-Tangen. at 3			
	15	Flex.-Circum. at 3			
	16	Shear-Force at 3			
TRAPAX	2	Harmonic or Point Angle			
	3	Radial (R)			
	4	Axial (Z)			
	5	Circum. (Theta-T)			
	6	Shear (ZR)			
	7	Shear (RT)			
	8	Shear (ZT)			
TRAPRG	2	Radial (x) at 1			
	3	Circum. (Theta) at 1			
	4	Axial (z) at 1			
	5	Shear (zx) at 1			
	6	Radial (x) at 2			
	7	Circum. (Theta) at 2			

(Continued)

Table 2. Element Stress Component Codes for Use on X-Y Output Command Operation Cards (continued)

(All components are stresses unless otherwise denoted)

Element Name	Real Element Stresses		Complex Element Stresses		
	Component Code	Component	Component Code	Component	Real-Mag. or Imag.-Phase
TRAPRG (cont.)	8	Axial (z) at 2			
	9	Shear (zx) at 2			
	10	Radial (x) at 3			
	11	Circum. (Theta) at 3			
	12	Axial (z) at 3			
	13	Shear (zx) at 3			
	14	Radial (x) at 4			
	15	Circum. (Theta) at 4			
	16	Axial (z) at 4			
	17	Shear (zx) at 4			
	18	Radial (x) at 5			
	19	Circum. (Theta) at 5			
	20	Axial (z) at 5			
	21	Shear (zx) at 5			
TRBSC		Same as TRIA1		Same as TRIA1	
TRIA1		Z1 = Fibre Distance 1		Z1 = Fibre Distance 1	
	3	Normal-x at Z1	3	Normal-x at 1	RM
	4	Normal-y at Z1	4	Normal-x at 1	IP
	5	Shear-xy at Z1	5	Normal-y at 1	RM
	6	θ-Shear Angle at Z1	6	Normal-y at 1	IP
	7	Major-Principal at Z1	7	Shear-xy at 1	RM
	8	Minor-Principal at Z1	8	Shear-xy at 1	IP
	9	Maximum Shear at Z1		Z2 = Fibre Distance 2	
		Z2 = Fibre Distance 2	10	Normal-x at 2	RM
	11	Normal-x at Z2	11	Normal-x at 2	IP
	12	Normal-y at Z2	12	Normal-y at 2	RM
	13	Shear-xy at Z2	13	Normal-y at 2	IP
	14	θ-Shear Angle at Z2	14	Shear-xy at 2	RM
	15	Major-Principal at Z2	15	Shear-xy at 2	IP
	16	Minor-Principal at Z2			
	17	Maximum-Shear at Z2			
TRIA2		Same as TRIA1		Same as TRIA1	
TRIAAX	2	Harmonic or Point Angle			
	3	Radial (R)			
	4	Axial (Z)			
	5	Circum. (Theta-T)			
	6	Shear (ZR)			
	7	Shear (RT)			
	8	Shear (ZT)			
TRIARG	2	Radial (x)			
	3	Circum. (Theta)			
	4	Axial (z)			
	5	Shear (zx)			

(Continued)

Table 2. Element Stress Component Codes for Use on X-Y Output Command Operation Cards (continued)

(All components are stresses unless otherwise denoted)

Element Name	Real Element Stresses		Complex Element Stresses		
	Component Code	Component	Component Code	Component	Real-Mag. or Imag.-Phase
TRMEM	2 3 4 5 6 7 8	Normal-x Normal-y Shear-xy θ-Shear Angle Major-Principal Minor-Principal Maximum Shear	2 3 4 5 6 7	Normal-x Normal-x Normal-y Normal-y Shear-xy Shear-xy	RM IP RM IP RM IP
TRPLT		Same as TRIA1		Same as TRIA1	
TUBE		Same as RØD		Same as RØD	
TWIST	2 3 4	Maximum Average Safety Margin	2 3 4 5	Maximum Maximum Average Average	RM IP RM IP
WEDGE		Same as TETRA		Same as TETRA	

Notes:

1. If output is magnitude/phase, the magnitude replaces the real part and the phase replaces the imaginary part.
2. The symbols SA1, SA2, SA3, SA4 and SB1, SB2, SB3, SB4 stand for stresses on end A and end B at locations C, D, E and F, respectively, as defined on the first continuation card of the PBAR bulk data card.

Table 3. Element Force Component Codes for Use on X-Y Output Command Operation Cards

(All components are element forces (or moments) unless otherwise indicated)

Element Name	Real Element Forces		Complex Element Forces		
	Component Code	Component	Component Code	Component	Real-Mag. or Imag.-Phase
BAR	2	Bend-Moment A1	2	Bend-Moment A1	RM
	3	Bend-Moment A2	3	Bend-Moment A2	RM
	4	Bend-Moment B1	4	Bend-Moment B1	RM
	5	Bend-Moment B2	5	Bend-Moment B2	RM
	6	Shear-1	6	Shear-1	RM
	7	Shear-2	7	Shear-1	RM
	8	Axial Force	8	Axial Force	RM
	9	Torque	9	Torque	RM
			10	Bend-Moment A1	IP
			11	Bend-Moment A2	IP
			12	Bend-Moment B1	IP
			13	Bend-Moment B2	IP
			14	Shear-1	IP
			15	Shear-2	IP
			16	Axial Force	IP
			17	Torque	IP
CØNRØD		Same as RØD		Same as RØD	
ELAS1	2	Force	2	Force	RM
			3	Force	IP
ELAS2	2	Force	2	Force	RM
			3	Force	IP
ELAS3	2	Force	2	Force	RM
			3	Force	IP
ELAS4	2	Force	2	Force	RM
			3	Force	IP
QDMEM2	2	Force 4 to 1			
	3	Force 2 to 1			
	4	Force 1 to 2			
	5	Force 3 to 2			
	6	Force 2 to 3			
	7	Force 4 to 3			
	8	Force 3 to 4			
	9	Force 1 to 4			
	10	Kick Force on 1			
	11	Shear-12			
	12	Kick Force on 2			
	13	Shear-23			
	14	Kick Force on 3			
	15	Shear-34			
	16	Kick Force on 4			
	17	Shear-41			
QDPLT		Same as TRIA1		Same as TRIA1	

(Continued)

Table 3. Element Force Component Codes for Use on X-Y Output Command Operation Cards (continued)

(All components are element forces (or moments) unless otherwise indicated)

Element Name	Real Element Forces		Complex Element Forces		
	Component Code	Component	Component Code	Component	Real-Mag. or Imag.-Phase
QUAD1		Same as TRIA1		Same as TRIA1	
QUAD2		Same as TRIA1		Same as TRIA1	
RØD	2	Axial Force	2	Axial Force	RM
	3	Torque	3	Axial Force	IP
			4	Torque	RM
			5	Torque	IP
SHEAR	2	Force Pts. 1, 3	2	Force Pts. 1, 3	RM
	3	Force Pts. 2, 4	3	Force Pts. 1, 3	IP
			4	Force Pts. 2, 4	RM
			5	Force Pts. 2, 4	IP
TRAPAX	2	Harmonic or Point Angle			
	3	Radial (R) at 1			
	4	Circum. (Theta-T) at 1			
	5	Axial (Z) at 1			
	6	Radial (R) at 2			
	7	Circum. (Theta-T) at 2			
	8	Axial (Z) at 2			
	9	Radial (R) at 3			
	10	Circum. (Theta-T) at 3			
	11	Axial (Z) at 3			
	12	Radial (R) at 4			
	13	Circum. (Theta-T) at 4			
	14	Axial (Z) at 4			
TRBSC		Same as TRIA1		Same as TRIA1	
TRIAAX	2	Harmonic or Point Angle			
	3	Radial (R) at 1			
	4	Circum. (Theta-T) at 1			
	5	Axial (Z) at 1			
	6	Radial (R) at 2			
	7	Circum. (Theta-T) at 2			
	8	Axial (Z) at 2			
	9	Radial (R) at 3			
	10	Circum. (Theta-T) at 3			
	11	Axial (Z) at 3			
TRIA1	2	Bend-Moment-x	2	Bend-Moment-x	RM
	3	Bend-Moment-y	3	Bend-Moment-y	RM
	4	Twist-Moment	4	Twist-Moment	RM
	5	Shear-x	5	Shear-x	RM
	6	Shear-y	6	Shear-y	RM
			7	Bend-Moment-x	IP
			8	Bend-Moment-y	IP
			9	Twist-Moment	IP

(Continued)

Table 3. Element Force Component Codes for Use on X-Y Output Command Operation Cards (continued)

(All components are element forces (or moments) unless otherwise indicated)

Element Name	Real Element Forces		Complex Element Forces		
	Component Code	Component	Component Code	Component	Real-Mag. or Imag.-Phase
TRIA1 (cont.)			10 11	Shear-x Shear-y	IP IP
TRIA2		Same as TRIA1		Same as TRIA1	
TRPLT		Same as TRIA1		Same as TRIA1	
TUBE		Same as RØD		Same as RØD	
TWIST	2 3	Moment Pts. 1, 3 Moment Pts. 2, 4	2 3 4 5	Moment Pts. 1, 3 Moment Pts. 1, 3 Moment Pts. 2, 4 Moment Pts. 2, 4	RM IP RM IP

X-Y Output Data Card XYPRINT - X-Y Print Output Command

Description: Causes generation of tabular printer output for the X-Y pairs.

Note: For the sake of convenience and completeness, this card and all other X-Y command operation cards are described together under the description of the XYPLØT command operation card. Please refer to that card for details.

X-Y Output Data Card XYPUNCH - X-Y Punch Output Command

Description: Causes generation of punched card output for the X-Y pairs.

Note: For the sake of convenience and completeness, this card and all other X-Y command operation cards are described together under the description of the XYPLØT command operation card. Please refer to that card for details.

X-Y Output Data Card YAXIS - Y-axis Plot Request

Description: Requests plotting of Y-axis.

Format and Example:

YAXIS = $\left\{\begin{matrix} \text{YES} \\ \underline{\text{NØ}} \end{matrix}\right\}$

YAXIS = YES

Option	Meaning
YES	Plot Y-axis.
NØ	Do not plot Y-axis.

Remarks: 1. This card is optional. It pertains to all types of plots (whole frame, upper half frame and lower half frame).

X-Y Output Data Card YBDIVISIØNS - Y-direction Spacing

Description: Specifies the spacing to be used along the Y-direction for non-log scales on lower half frame plots only.

Format and Example:

YBDIVISIONS = $\left\{\begin{matrix} n \\ \underline{5} \end{matrix}\right\}$

YBDIVISIONS = 4

Option	Meaning
n	Number of uniform spaces to be used along the Y-direction for whichever of the following are called for: BLEFT TICS, BRIGHT TICS, YAXIS (Integer > 0). Applicable only to non-log scales.

Remarks: 1. This card is optional. It pertains only to lower half frame plots.

X-Y Output Data Card YBGRID LINES - Y-grid Lines Request

Description: Requests the drawing of grid lines parallel to the Y-axis on lower half frame plots only.

Format and Example:

YBGRID LINES = {YES / NØ}

YBGRID LINES = YES

Option	Meaning
YES	Draw grid lines parallel to the Y-axis at locations requested for tic marks.
NØ	Do not draw grid lines parallel to the Y-axis.

Remarks: 1. This card is optional. It pertains only to lower half frame plots.

X-Y Output Data Card YBINTERCEPT - X-axis Position

Description: Specifies the location on the Y-axis where the X-axis will be drawn on lower half frame plots only.

Format and Example:

YBINTERCEPT = $\left\{\begin{matrix} y_c \\ \underline{0.0} \end{matrix}\right\}$

YBINTERCEPT = 1.0

Option	Meaning
y_c	X-axis will have its y-coordinate = y_c (Real)

Remarks: 1. This card is optional. It pertains only to lower half frame plots.

X-Y Output Data Block YBLØG - Logarithmic Y-coordinate Request

Description: Requests logarithmic scale for Y-coordinates on lower half frame plots only.

Format and Example:

$$\text{YBLØG} = \begin{Bmatrix} \text{YES} \\ \underline{\text{NØ}} \end{Bmatrix}$$

YBLØG = YES

Option	Meaning
YES	Use logarithmic scale for Y-coordinates.
NØ	Use linear scale for Y-coordinates.

Remarks:

1. This card is optional. It pertains only to lower half frame plots.
2. See Remark 2 under the description of the XLØG card for default values for tic divisions on log plots.

X-Y Output Data Card YBMAX - Upper Limit of Ordinate

Description: Specifies the upper limit of the ordinate of a curve on lower half frame plots only.

Format and Example:

YBMAX = y

YBMAX = 8.0

Option	Meaning
y	Upper Limit of the ordinate (Real).

Remarks:

1. This card is optional. It pertains only to lower half frame plots.
2. If this card is not used, the default value is chosen so as to accommodate all points.

X-Y Output Data Card YBMIN - Lower Limit of Ordinate

Description: Specifies the lower limit of the ordinate of a curve on lower half frame plots only.

Format and Example:

YBMIN = y

YBMIN = 2.0

Option	Meaning
y	Lower Limit of the ordinate (Real).

Remarks:
1. This card is optional. It pertains only to lower half frame plots.
2. If this card is not used, the default value is chosen so as to accommodate all points.

X-Y Output Data Card YBTITLE - Y-axis Title

Description: Specifies the title for the Y-axis on lower half frame plots only.

Format and Example:

YBTITLE = title

YBTITLE = RESPØNSE ØF PØINT 1

Option	Meaning
title	Any BCD string to be used as the title for the Y-axis.

Remarks: 1. This card is optional. It pertains only to lower half frame plots.

2. The data for this card must be specified on only one physical card.

X-Y Output Data Card YBVALUE PRINT SKIP - Y-tic Skip Specification

Description: Specifies the number of tic marks to be skipped between labeled tic marks on the Y-axis on lower half frame plots only.

Format and Example:

YBVALUE PRINT SKIP = $\begin{Bmatrix} n \\ \underline{0} \end{Bmatrix}$

YBVALUE PRINT SKIP = 1

Option	Meaning
n	Number of tic marks to skipped between labeled tic marks on the Y-axis (Integer ≥ 0). Thus, every $(n + 1)^{th}$ tic mark on the Y-axis will be labeled.

Remarks: 1. This card is optional. It pertains only to lower half plots.

X-Y Output Data Card YDIVISIØNS - Y-direction Spacing

Description: Specifies the spacing to be used along the Y-direction for non-log scales on whole frame plots only.

Format and Example:

$$\text{YDIVISIØNS} = \left\{ \begin{matrix} n \\ \underline{5} \end{matrix} \right\}$$

YDIVISIØNS = 4

Option	Meaning
n	Number of uniform spaces to be used along the Y-direction for whichever of the following are called for: LEFT TICS, RIGHT TICS, YAXIS (Integer > 0). Applicable only to non-log scales.

Remarks: 1. This card is optional. It pertains only to whole frame plots.

X-Y Output Data Card YGRID LINES - Y-grid Lines Request

Description: Requests the drawing of grid lines parallel to the Y-axis on whole frame plots only.

Format and Example:

YGRID LINES = {YES / NØ}

YGRID LINES = YES

Option	Meaning
YES	Draw grid lines parallel to the Y-axis at locations requested for tic marks.
NØ	Do not draw grid lines parallel to the Y-axis.

Remarks: 1. This card is optional. It pertains only to whole frame plots.

X-Y Output Data Card YINTERCEPT - X-axis Position

Description: Specifies the location on the Y-axis where the X-axis will be drawn on whole frame plots only.

Format and Example:

YINTERCEPT = $\left\{\begin{matrix} y_c \\ \underline{0.0} \end{matrix}\right\}$

YINTERCEPT = 1.0

Option	Meaning
y_c	X-axis will have its y-coordinate = y_c (Real)

Remarks: 1. This card is optional. It pertains only to whole frame plots.

X-Y Output Data Block YLØG - Logarithmic Y-coordinate Request

Description: Requests logarithmic scale for Y-coordinates on whole frame plots only.

Format and Example:

$$\text{YLØG} = \begin{Bmatrix} \text{YES} \\ \underline{\text{NØ}} \end{Bmatrix}$$

YLØG = YES

Option	Meaning
YES	Use logarithmic scale for Y-coordinates.
NØ	Use linear scale for Y-coordinates.

Remarks:

1. This card is optional. It pertains only to whole frame plots.
2. See Remark 2 under the description of the XLØG card for default values for tic divisions on log plots.

X-Y Output Data Card YMAX - Upper Limit of Ordinate

Description: Specifies the upper limit of the ordinate of a curve on whole frame plots only.

Format and Example:

YMAX = y

YMAX = 8.0

Option	Meaning
y	Upper Limit of the ordinate (Real).

Remarks:
1. This card is optional. It pertains only to whole frame plots.
2. If this card is not used, the default value is chosen so as to accommodate all points.

X-Y Output Data Card YMIN - Lower Limit of Ordinate

Description: Specifies the lower limit of the ordinate of a curve on whole frame plots only.

Format and Example:

YMIN = y

YMIN = 2.0

Option	Meaning
y	Lower Limit of the ordinate (Real).

Remarks:

1. This card is optional. It pertains only to whole frame plots.
2. If this card is not used, the default value is chosen so as to accommodate all points.

X-Y Output Data Card YPAPER - Plot Frame Y-dimension

Description: Specifies the Y-dimension of the plot frame (x by y) for table and drum plotters. (For microfilm plotters, the plot frame size is set at 10.23 inches x 10.23 inches and is not under user control).

Format and Example:

YPAPER = y

YPAPER = 12.0

Option	Meaning
y	Y-dimension of the plot frame in inches ($0.0 < y \leq 30.0$)

Remarks:

1. This card is optional. It pertains to all types of plots (whole frame, upper half frame and lower half frame).

2. If this card is not used, the following default values are used:

Plotter model	Default value for y (inches)
Table	8.5
Drum	30.0

3. See Section 4.1.1 for an important discussion on plot frame size and character size.

X-Y Output Data Card <u>YTDIVISIONS</u> - Y-direction Spacing

<u>Description</u>: Specifies the spacing to be used along the Y-direction for non-log scales on upper half frame plots only.

<u>Format and Example</u>:

$$\text{YTDIVISIONS} = \begin{Bmatrix} n \\ \underline{5} \end{Bmatrix}$$

YTDIVISIONS = 4

Option	Meaning
n	Number of uniform spaces to be used along the Y-direction for whichever of the following are called for: TLEFT TICS, TRIGHT TICS, YAXIS (Integer > 0). Applicable only to non-log scales.

<u>Remarks</u>: 1. This card is optional. It pertains <u>only to upper half frame plots</u>.

X-Y Output Data Card YTGRID LINES - Y-grid Lines Request

Description: Requests the drawing of grid lines parallel to the Y-axis on upper half frame plots only.

Format and Example:

YTGRID LINES = {YES / NØ}

YTGRID LINES = YES

Option	Meaning
YES	Draw grid lines parallel to the Y-axis at locations requested for tic marks.
NØ	Do not draw grid lines parallel to the Y-axis.

Remarks: 1. This card is optional. It pertains only to upper half frame plots.

X-Y Output Data Card YTINTERCEPT - X-axis Position

Description: Specifies the location on the Y-axis where the X-axis will be drawn on upper half frame plots only.

Format and Example:

YTINTERCEPT = $\begin{Bmatrix} y_c \\ 0.0 \end{Bmatrix}$

YTINTERCEPT = 1.0

Option	Meaning
y_c	X-axis will have its y-coordinate = y_c (Real)

Remarks: 1. This card is optional. It pertains only to upper half frame plots.

X-Y Output Data Card YTITLE - Y-axis Title

Description: Specifies the title for the Y-axis on whole frame plots only.

Format and Example:

YTITLE = title

YTITLE = RESPØNSE ØF PØINT 1

Option	Meaning
title	Any BCD string to be used as the title for the Y-axis.

Remarks: 1. This card is optional. It pertains only to whole frame plots.

X-Y Output Data Block YTLØG - Logarithmic Y-coordinate Request

Description: Requests logarithmic scale for Y-coordinates on upper half frame plots only.

Format and Example:

$$\text{YTLØG} = \begin{Bmatrix} \text{YES} \\ \underline{\text{NØ}} \end{Bmatrix}$$

YTLØG = YES

Option	Meaning
YES	Use logarithmic scale for Y-coordinates.
NØ	Use linear scale for Y-coordinates.

Remarks:

1. This card is optional. It pertains only to upper half frame plots.
2. See Remark 2 under the description of the XLØG card for default values for tic divisions on log plots.

X-Y Output Data Card YTMAX - Upper Limit of Ordinate

Description: Specifies the upper limit of the ordinate of a curve on upper half frame plots only.

Format and Example:

YTMAX = y

YTMAX = 8.0

Option	Meaning
y	Upper Limit of the ordinate (Real).

Remarks: 1. This card is optional. It pertains only to upper half frame plots.

2. If this card is not used, the default value is chosen so as to accommodate all points.

X-Y Output Data Card YTMIN - Lower Limit of Ordinate

Description: Specifies the lower limit of the ordinate of a curve on upper half frame plots only.

Format and Example:

YTMIN = y

YTMIN = 2.0

Option	Meaning
y	Lower Limit of the ordinate (Real).

Remarks:
1. This card is optional. It pertains only to upper half frame plots.
2. If this card is not used, the default value is chosen so as to accommodate all points.

X-Y Output Data Card YTTITLE - Y-axis Title

Description: Specifies the title for the Y-axis on upper half frame plots only.

Format and Example:

YTTITLE = title

YTTITLE = RESPØNSE ØF PØINT 1

Option	Meaning
title	Any BCD string to be used as the title for the Y-axis.

Remarks: 1. This card is optional. It pertains only to upper half frame plots.

2. The data for this card must be specified on only one physical card.

X-Y Output Data Card YTVALUE PRINT SKIP - Y-tic Skip Specification

Description: Specifies the number of tic marks to be skipped between labeled tic marks on the Y-axis on upper half frame plots only.

Format and Example:

YTVALUE PRINT SKIP = $\left\{\begin{matrix} n \\ \underline{0} \end{matrix}\right\}$

YTVALUE PRINT SKIP = 1

Option	Meaning
n	Number of tic marks to skipped between labeled tic marks on the Y-axis (Integer ≥ 0). Thus, every $(n + 1)^{th}$ tic mark on the Y-axis will be labeled.

Remarks: 1. This card is optional. It pertains only to upper half plots.

X-Y Output Data Card YVALUE PRINT SKIP - Y-tic Skip Specification

Description: Specifies the number of tic marks to be skipped between labeled tic marks on the Y-axis on whole frame plots only.

Format and Example:

YVALUE PRINT SKIP = $\left\{\begin{matrix} n \\ \underline{0} \end{matrix}\right\}$

YVALUE PRINT SKIP = 1

Option	Meaning
n	Number of tic marks to skipped between labeled tic marks on the Y-axis (Integer ≥ 0). Thus, every $(n + 1)^{th}$ tic mark on the Y-axis will be labeled.

Remarks: 1. This card is optional. It pertains only to whole frame plots.

4.4 NASTRAN GENERAL PURPOSE PLOTTER (NASTPLT) FILE

As indicated in Section 4.1, the NASTRAN plotting software is completely independent of any particular plotting hardware. This protects the NASTRAN software from being impacted by changes, additions or deletions made to any particular plotting hardware. Instead, the plot file produced by NASTRAN (the actual NASTRAN plot output may reside either on physical tape or on mass storage device) is meant for a hypothetical plotter termed the NASTRAN General Purpose Plotter (NASTPLT) and is not suitable for use directly by any particular plotter. In order to use this NASTPLT file to obtain plots on any particular user's plotter, the user's installation must have available an external translator program to interpret this plot file and create plots on the user's plotter. Thus, in order to obtain plots using NASTRAN, two programs must be run: first, NASTRAN itself, to generate the NASTPLT file; and then the external translator program, to interpret this plot file.

The purpose of this section is to explain the characteristics and construction of the NASTPLT file, so that a user/programmer will be able to write a program to translate this plot file for his plotter. Understanding the overall logic used by the NASTRAN plotter software package in producing a plot file will simplify the task of writing this translator program. It is therefore recommended that the user/programmer familiarize himself not only with this section, but also with Section 6.10 of the Programmer's Manual, dealing with the plotting software in NASTRAN.

The NASTPLT file is composed of a simple set of elementary plot operations, which can be easily deciphered by a FØRTRAN program on any digital computer. As each operation is deciphered, the translator program should direct the receiving plotter to appropriate action. This would normally be done by using the installation software to interface between the translator program and the receiving plotter. If appropriate external translator programs are written, it is thus possible to obtain NASTRAN plots on any plotter.

4.4.1 Description of the NASTPLT File

The NASTPLT file is a fixed-length record file. An end-of-file mark follows the last plot only. Each record of the file is composed of 3000 n-bit bytes (or characters), each byte (or character) containing an unsigned integer. The value of n (the number of bits per byte) depends on the machine type. On the CDC and UNIVAC versions, n is equal to 6; on the IBM and DEC VAX versions, n is equal to 8. Thus, each record of 3000 unsigned integers consists of 300 words on the CDC (where the word length is 60 bits), 500 words on the UNIVAC (word length: 36 bits) and 750 words on the IBM and DEC VAX (word length: 32 bits).

Each record of the NASTPLT file is composed of 100 plot commands, each command being composed of 30 bytes or unsigned integers (3 words on the CDC, 5 words on the UNIVAC and 15 half-words on the IBM and DEC VAX). Not all plot commands will have useful information in all 30 bytes. Some commands use only two of the 30 bytes, while others use 22. The general format of each command is as follows:

$$PCR_4R_3R_2R_1R_0S_4S_3S_2S_1S_0T_4T_3T_2T_1T_0U_4U_3U_2U_1U_000000000 \quad ,$$

where:

P = plot command,

C = control index,

R_i = decimal digit of an integer called R,

S_i = decimal digit of an integer called S,

T_i = decimal digit of an integer called T,

U_i = decimal digit of an integer called U,

0 = zero.

The plot command is an n-bit integer, any one of seven (7) possible plot commands, as follows:

0 = no operation,

1 = start new plot,

2 = select camera,

3 = skip to a new frame,

4 = type a character (may also = 14),

5 = draw a line (may also = 15),

6 = draw an axis (may also = 16).

The control index is also an n-bit integer. It may be a pen number, a line density, a camera number, or a pointer into a list of characters and symbols. The four integer values (R,S,T,U) specified in a command must be reconstructed by the external translator program. Each integer value is represented in the command as follows:

$$d_4d_3d_2d_1d_0 \quad ,$$

where the original integer value is given by:

$$d_4 10^4 + d_3 10^3 + d_2 10^2 + d_1 10^1 + d_0 10^0 \quad .$$

The significance of each of the four integer values (R,S,T,U) may vary from one plot command to another. This is discussed in the next section.

4.4.2 Description of the Plot Commands on the NASTPLT File

The seven possible plot commands on the NASTPLT file are described here.

The no-operation (0) command is simply a padding for plot records which may otherwise have been less than 300 bytes long. All 30 bytes of this command will be zero.

The start-new-plot (1) command will always be the first command introducing each new plot. The first integer (R) will be the plot number. The second and third integers (S and T) are the maximum x and y values specified in any other command for this plot. The minimum x and y values are always zero and are therefore not specified in the start new plot command. If necessary, the translator program can use these maximum x and y values to scale subsequent integer values so that the plot will not exceed the limits of the plotting surface. The plot number is included because some plotters require the plot number as part of the first command for each new plot. In addition, if the receiving plotter is a table plotter, the translator program should issue a command to the plotter which will stop it so that the plotter operator can change the paper. If the plotter is a drum plotter, the translator program must skip a sufficient amount of paper to ensure that the previous plot will not be over-plotted. And if the receiving plotter is a microfilm plotter, nothing else need be done.

The select-camera (2) command uses only the control index (C). The remaining 28 bytes are always zeros. This command is meaningful only on a microfilm plotter having both film and hardcopy output. The control index is the camera or output medium request number: 1 = film only; 2 = hardcopy (paper) only; and 3 = both. Upon receiving this command, the translator program should issue a command to the receiving plotter selecting the requested camera or output medium, then this command should be ignored.

The skip-to-a-new-frame (3) command also uses only the control index. The remaining 28 bytes are always zeros. This command is meaningful only on a microfilm plotter. The control index is the camera or output medium request number: 1 = film only; 2 = hardcopy (paper) only; and 3 = both. The appropriate camera will have already been selected in a previous select-camera command. The only reason the camera number is included in this command is because some microfilm plotters require the camera or output medium to be specified in both select camera and skip frame commands. Upon receiving this command, the translator program should issue a command to the receiving plotter

to skip to a new frame. If the receiving plotter is not a microfilm plotter, then this command should be ignored. Note: at least one skip-to-a-new-frame command will appear after each start-new-plot command and before the next start-new-plot command.

The type-character (4), draw-line (5), and draw-axis (6) commands will always occur in sets, i.e., a set of type-character commands, a set of draw-line commands, a set of draw-axis commands. There may be more than one set of each type of command, but, within a set, the commands will all be of the same type. This is done because on some plotters it is very inefficient to frequently change modes (e.g., typing mode, line drawing mode) of operation. The plot command of the first command in a set will always = 10 + the basic plot command value, i.e., type-character = 14; draw-line = 15; and draw-axis = 16. In all subsequent plot commands in the set, the plot command value will always equal the basic plot command value.

For a type-character command, the control index is a pointer into a specific list of characters and special symbols. The list of characters and symbols to which the pointer applies is given in Table 1. The first two integer values (R and S) in the plot command represent the x and y coordinates of the point on the plotting surface at which the center of the character or symbol should be typed. The next integer value (T) represents the character scale value (see the description of the CSCALE card in Section 4.2.2.4) to be used in the plotting. The remaining 13 bytes of the command are always zeros. Upon receipt of a type-character command, the translator program should issue a command to the receiving plotter to type the requested character or special symbol (using the CSCALE value, if possible and appropriate) at the specified point. Of course, there is no guarantee that all the possible characters and special symbols can be typed by the receiving plotter. If any character or special symbol cannot be typed by the receiving plotter, the translator program will then have to make a substitution or not type the character at all.

For a draw-line command, the control index is either a pen number (for table and drum plotters) or a line density (for microfilm plotters). If the receiving plotter is a microfilm plotter, it is recommended that the translator program simply draw the line as many times as is indicated by the line density value, rather than using any special density settings available on the plotter hardware. The first two integer values (R and S) represent the x and y coordinates of the starting point of the line. The next two integer values (T and U) represent the x and y coordinates of the ending point of the line. The last 8 bytes of the command are always zeros. Upon receipt of this command, the translator program should issue a command to the receiving plotter to draw the line. Note: some plotters require that a line be broken into a series of

Table 1. Characters and symbols indicated by the pointer in the <u>type-character</u> plot command

Pointer Value	Character/Symbol		Pointer Value	Character/Symbol
1	0		27	Q
2	1		28	R
3	2		29	S
4	3		30	T
5	4		31	U
6	5		32	V
7	6		33	W
8	7		34	X
9	8		35	Y
10	9		36	Z
11	A		37	(
12	B		38	)
13	C		39	+
14	D		40	-
15	E		41	*
16	F		42	/
17	G		43	=
18	H		44	.
19	I		45	,
20	J		46	$
21	K		47	!
22	L		48	•
23	M		49	○
24	N		50	□
25	O		51	◊
26	P		52	△

short lines. If this is the case on the receiving plotter, the translator program will have to accomplish this task unless the installation software makes provision for this automatically.

The draw-axis command is identical to the draw-line command. The only difference is in the orientation of the drawn line. The line drawn by a draw-axis command will always be either horizontal or vertical. For most plotters, the translator program will handle this command just like a draw-line command. However, some plotters, which would ordinarily require that lines be broken into a series of short lines, may have a special command available to draw a horizontal or vertical line of any length. For these few plotters only will this command have any special significance in the translator program. If such is the situation, the translator program, upon receipt of this command, should issue a command to the receiving plotter to draw the axis. Otherwise, the translator program should simply issue a command to the receiving plotter to draw a line representing the axis.

5. DIRECT MATRIX ABSTRACTION

5.1 INTRODUCTION

In addition to using the rigid formats provided automatically by NASTRAN, the user may wish to execute a series of modules in a different manner than provided by a rigid format. Or, he may wish to perform a series of matrix operations which are not contained in any existing rigid format. If the modifications to an existing rigid format are minor, the ALTER feature described in Section 2 may be employed. Otherwise, a user-written Direct Matrix Abstraction Program (DMAP) should be used.

DMAP is the user-oriented language used by NASTRAN to solve problems. A rigid format is basically a collection of statements in this language. DMAP, like English or FØRTRAN, has many grammatical rules which must be followed to be interpretable by the NASTRAN DMAP compiler. Section 5.2 provides the user with the rules of DMAP which will allow him to understand the rigid format DMAP sequences, write ALTER packages, and construct his own DMAP sequences using the many modules contained in the NASTRAN DMAP repertoire.

Section 5.3 is an index of matrix, utility, user and executive DMAP modules which are contained in Sections 5.4 thru 5.7 respectively.

Sections 5.4 thru 5.7 describe individually the many nonstructurally oriented modules contained in the NASTRAN library. Section 5.8 provides several examples of DMAP usage.

User-written modules must conform to the rules and usage conventions described herein.

Section 5.8 illustrates the use of DMAP operations in both the standard method (as rigid formats are written) and in the improved method.

Section 5.9 describes the automatic ALTERs to a rigid format which result from each of the Automated Multi-stage Substructuring commands invoked by the user.

Section 5.10 contains descriptions and uses of functional modules which are of general utility to the user but have not been permanently incorporated into the rigid formats.

5.2 DMAP RULES

Grammatically, DMAP instructions consist of two types: Executive Operation Instructions and Functional Module Instructions. Grammatical rules for these two types of instructions will be discussed separately in subsequent sections.

Functional modules are arbitrarily classified as structural modules, matrix operation modules, utility modules, or user-generated modules.

The DMAP sequence itself consists of a series of DMAP instructions or statements, the first of which is BEGIN or XDMAP and the last of which is END. The remaining statements consist of Executive Operation instructions and Functional Module calls.

5.2.1 DMAP Rules for Functional Module Instructions

The primary characteristic of the Functional Module DMAP instruction is its prescribed format. The general form of the Functional Module DMAP statement is:

```
MØD   I1,I2,---,Im/Ø1,Ø2,---,Øn/a1,b1,p1/a2,b2,p2----/az,bz,pz  $

   where   MØD is the DMAP Functional Module name,
           Ii; i = 1,m are the Input Data Block names,
           Øi; i = 1,n are the Øutput Data Block names,
   and     ai,bi,pi; i = 1,z are the Parameter Sections.
```

In the general form shown above, commas (,) are used to separate several like items while slashes (/) are used to separate sections from one another. The module name is separated from the rest of the instruction by a blank or a comma (,). The dollar sign ($) is used to end the instruction and is not required unless the instruction ends in the delimiter /. A DMAP statement is restricted to columns 1 through 72. Information beyond column 72 is ignored. If the entire DMAP instruction does not fit on one card, the last delimiter (not followed by a $ sign) causes the next card to be read as a continuation. Thus, one DMAP instruction may require several cards. Blanks may be used in conjunction with any of the above delimiters for ease of reading. If it is desired to preserve the output alignment of the printed instructions, the module name is begun in column 1 and the rest of the instruction is begun in column 10 when supplying alters to a Rigid Format.

A functional module communicates with other modules and the executive system entriely through its inputs, outputs and parameters. The characteristics or attributes of each functional module are contained in the Module Properties List (MPL) described in Section 2.4 of the Programmer's

Manual and are reflected in the DMAP Module Descriptions that follow in Section 5.3 and in the Module Functional Descriptions contained in Chapter 4 of the Programmer's Manual. The module name is a BCD value (which consists of an alphabetic character followed by up to seven additional alphanumeric characters) and must correspond to an entry in the MPL. A Data Block name may be either a BCD value or null. The absence of a BCD value indicates that the Data Block is not needed for a particular application.

5.2.1.1 Functional Module DMAP Statements

Each Functional Module DMAP statement must conform to the MPL regarding:

1. Name spelling
2. Number of input data blocks
3. Number of output data blocks
4. Number of parameters
5. Type of each parameter

Note: See Sections 5.2.1.3 and 5.2.1.4 for allowable exceptions to these rules.

5.2.1.2 Functional Module Names

The only Functional Module DMAP names allowed are those contained in the MPL. Therefore, if a user wishes to add a module, he must either use one of the User Module names provided (see Section 5.6) or add a name to the MPL. The Programmer's Manual should be consulted when adding a new module to NASTRAN.

5.2.1.3 Functional Module Input Data Blocks

In most cases an input data block should have been previously defined in a DMAP program before it is used. However, there may be instances in which a module can handle, or may even expect, a data block to be undefined at the time the module is initially called. An input data block is previously defined if it appears as an output data block in a previous DMAP instruction, as output from the Input File Processor, any user-input (via Bulk Data Cards) DMI or DTI data block name, or exists on the Old Problem Tape in a restart problem. Although the number of data blocks is prescribed, if any number of final data blocks are null, they may be omitted from the section. For example, the module TABPT, which uses five input data blocks, may be defined by:

```
TABPT   GEØM1,,,, //  $
```

or

```
TABPT   GEØM1 //  $
```

A potentially fatal error message (See Section 5.2.1.7) will be issued at compilation time to warn the user that a discrepancy in the data block name list has been detected. This is also true in the event that a previously undefined data block is used as input. Also, see the "error-level" option on the XDMAP compiler option card which may be invoked by the user to terminate execution in the event of such errors.

5.2.1.4 Functional Module Output Data Blocks

In general, a data block name will appear as output only once. However, there are cases in which an output data block may be of no subsequent use in a DMAP program. In such a case the name may be used again, but caution should be used when employing such techniques. Although the number of output data blocks is prescribed, the data block name list may be abbreviated in the manner of Section 5.2.1.3. Potentially fatal error messages will warn the user if possible ambiguities may occur from these usages.

5.2.1.5 Functional Module Parameters

Parameters may serve many purposes in a DMAP program. They may pass data values into and/or out from a module, or they may be used as flags to control the computational flow within the module or the DMAP program. There are two allowable forms of the parameter section of the DMAP instruction. The first explicitly states the attributes of the parameters, while the second is a briefer simplified specification. The general form of the formal parameter section is

/ ai,bi,pi /

where the allowable parameter specifications are:

ai = {
- V — Parameter value is variable and may be changed by the module during execution.
- C — Parameter value is prescribed initially by the user and is an unalterable constant.
- S — Parameter is of type V, and will be saved automatically at completion of module. (See description of the SAVE instruction.)

bi = {
- Y — Initial parameter value may be specified on a PARAM Bulk Data card.
- N — Initial parameter value may <u>not</u> be specified on a PARAM Bulk Data card.

pi = {
- PNAME = v
- PNAME
- v

PNAME is a BCD name selected by the user to represent a given parameter.

The default values for ai and bi depend on the value given for pi, as described below. The three forms available for pi require additional clarification. The symbol 'v' represents an

actual numeric value for the parameter and may be used only when ai = C and bi = N. The other forms will be clarified by the examples found at the end of this section. Each parameter has an initial value which is established when the DMAP sequence is compiled during execution of the NASTRAN preface. The means by which initial values are established for all DMAP parameters will be explained by the symbolic examples that follow. The value used at execution time may differ from the initial value if and only if the module changes the value, if ai = "V", and the parameter name appears in a SAVE (see Section 5.7) instruction immediately following the module.

The formal parameter specifications defined above can, in frequently encountered instances, be greatly simplified. Situations where these simplifications may be used are:

1. / C,N,v / can be written as / v /

   The value 'v' is written exactly as it would be in the formal specification with the exception of BCD constant parameters, in which case the BCD string is enclosed by asterisks, i.e., / *STRING* / .

2. / V,N,PNAME / can be written as / PNAME /

   / V,N,PNAME=v / can be written as / PNAME=v /

   Again, in the case where the value 'v' appears, it is written exactly as in the case of the formal specification. In this case, BCD strings are not delimited by asterisks.

3. / (default value) / can be written as //

   If a particular parameter has a predefined default value specified in the Module Properties List (MPL), and the user wishes to choose this value, then it is necessary only to code successive slashes. If a parameter does not have a default value, an error message will be issued.

Six parameter types are available and the type of each parameter is given in the MPL and may not be changed. The types and examples of values as they would be written in DMAP are given below:

Parameter Type	Value Examples		
Integer	7	-2	0
Real	-3.6	2.4+5	0.01-3
BCD	VAR01	STRING3	B3R56
Double Precision	2.5D-3	1.354D7	
Complex Single Precision		(1.0,-3.24)	
Complex Double Precision		(1.23D-2,-3.67D2)	

Many possible forms of the parameter section may be used. The following examples will help to clarify the possibilities.

// This is equivalent to / C,N,v / where v is the MPL default value which must exist.

/ C,Y,v	Constant input parameter Examples: / C,N,0 / C,N,BKLO / C,N,(1.0,-1.0) or / 0 / *BKLO* / (1.0,-1.0) In the examples shown, both in formal and simplified form, the values 0 (integer), BKLO (BCD), and 1.0-i1.0 (complex single precision) are defined.
/ C,Y,PNAME	Constant input parameter; MPL default value is used unless a PARAM Bulk Data card referencing PNAME is present. Error condition is detected if either no PARAM card is present or if no MPL default value exists.
/ C,Y,PNAME=v	Constant input parameter; the value v is used unless a PARAM Bulk Data card referencing PNAME is present.
/ V,Y,PNAME or / V,Y,PNAME=v	Variable parameter; may be input, output, or both; initial value is the first of 1. value from the most recently executed SAVE instruction, if any 2. value from PARAM Bulk Data card referencing PNAME will be used if present in Bulk Data Deck 3. v, if present in DMAP instruction 4. MPL default value, if any 5. 0 If a parameter is output from a functional module and if the output value is to be carried forward, a SAVE instruction <u>must immediately</u> follow the DMAP instruction in which the parameter is generated.
/ V,N,PNAME or / PNAME or / V,N,PNAME=v or / PNAME=v	Variable parameter; may be input, output, or both; initial value is the first of 1. value from the most recently executed SAVE instruction, if any 2. v, if present in DMAP instruction 3. MPL default value, if any 4. 0

5.2.1.6 DMAP Compiler Options - The XDMAP Instruction (see Section 5.7)

The user has the ability to elect several options when compiling and executing a DMAP program by including an XDMAP compiler option instruction in the program. Similarly, the Rigid Formats may be altered by replacing the BEGIN statement with XDMAP to invoke the same options. The available options are:

<u>GØ</u> (default) or <u>NØGØ</u>

The GØ option compiles and executes the program, while NØGØ terminates the job at the conclusion of compilation.

<u>LIST</u> or <u>NØLIST</u> (default)

This option produces a DMAP program source listing.

<u>DECK</u> or <u>NØDECK</u> (default)

This option will produce a punched card deck of the program.

<u>ØSCAR</u> or <u>NØØSCR</u> (default)

If the ØSCAR option is selected, a complete listing of the Operation Sequence Control Array will be given.

REF or NØREF (default)

This option will produce a complete cross reference of variable parameters, data block names, and module calls for the DMAP program.

ERR=0 or 1 or 2 (default)

This option specifies the error level, '0' for WARNING, '1' for PØTENTIALLY FATAL, and '2' for FATAL ERRØR MESSAGE, at which termination of the job will occur, see Section 5.2.1.7 for further explanation.

The complete description of the XDMAP card may be found in the DMAP Module Description section. Note that an XDMAP card need not appear when all default values are elected, but may be replaced with a BEGIN instruction.

5.2.1.7 Extended Error Handling Facility

There are three levels of error messages generated during the compilation of a DMAP sequence. These levels are WARNING MESSAGE, PØTENTIALLY FATAL ERRØR MESSAGE, and FATAL ERRØR MESSAGE. The user has, through available compiler options, the ability to specify the error level at which the job will be terminated. (See Section 5.2.1.6 for the manner of specification.) The class of PØTENTIALLY FATAL ERRØR MESSAGES is generated by certain compiler conveniences which, if not fully understood by the user, could cause an erroneous or incorrect execution of the DMAP sequence. The default value for the error level is that of the FATAL ERRØR.

5.2.2 DMAP Rules for Executive Operation Instructions

Each executive operation statement has its own format which is generally open-ended, meaning the number of inputs, outputs, etc. is not prescribed. Executive operation instructions or statements are divided into general categories as follows:

1. Declarative instructions FILE, BEGIN, LABEL, XDMAP, and PRECHK which aid the DMAP compiler and the file allocator as well as provide user convenience.

2. Instructions CHKPNT, EQUIV, PURGE, and SAVE which aid the NASTRAN Executive System in allocating files, interfacing between functional modules, and in restarting a problem.

3. Control instructions REPT, JUMP, CØND, EXIT, and END which control the order in which DMAP instructions are executed.

The rules associated with the executive operation instructions are distinct for each instruction and are discussed individually in Section 5.7.

5.2.3 Techniques and Examples of Executive Module Usage

Even though the DMAP program may be interpretable by the DMAP compiler it does not guarantee that the program will yield the desired results. Therefore, this section is provided to acquaint the DMAP programmer with techniques and examples used in writing DMAP programs. In particular, the instructions REPT, FILE, EQUIV, PURGE, and CHKPNT will now be discussed in some detail. The DMAP modules available are listed in Section 5.3.

The new DMAP user should read Sections 5.4 through 5.7 to obtain the necessary knowledge of terminology before reading this section.

The data blocks and functional modules referenced in the following examples are fictitious and have no relationship to any real data blocks or functional modules.

A data block is described as having a status of "not generated," "generated" or "purged." A status of not generated means that the data blocks is available for generation by appearing as output in a functional module. A status of generated means that the data block contains data which is available for input to a subsequent module. A status of purged means that the data block cannot be generated and any functional module attempting to use this data block as input or output will be informed that the purged data block is not available for use.

5.2.3.1 The REPT and FILE Instructions (see Section 5.7)

The DMAP instructions bounded by the REPT instruction and the label referenced by the REPT instruction are referred to as a loop. The location referenced by the REPT is called the top of the loop. In many respects a DMAP loop is like a giant functional module since it requires inputs and generates output data blocks which usually can be handled correctly by the File Allocator (see Section 4.9 of the Programmer's Manual) without any special action by the DMAP programmer. The one exception is a data block that is not referenced outside the loop (i.e., an internal data block with respect to the loop). The file allocator considers internal data blocks as scratch data blocks to be used for the present pass through the loop but not to be saved for input at the top of the loop. Should the DMAP programmer desire to save an internal data block, he may do so by declaring the data block SAVE in the FILE instruction.

When the REPT instruction transfers control back to the top of the loop, the status of all internal data blocks is changed to "not generated" unless the internal data block is declared SAVE or APPEND in a FILE instruction. It should also be noted that equivalences established between internal data blocks (not declared saved) and data blocks referenced outside the loop are not carried over for the next time through the loop. The equivalence must be re-established each time through the loop. Data blocks generated by the Input File Processor are considered referenced outside of all DMAP loops.

EXAMPLE using REPT and FILE instructions.

```
          BEGIN     $
          FILE      X=SAVE / Y=APPEND / Z=APPEND $
          LABEL     L1 $
          MØD1      B/W,Y $
          CØND      L3,PX $
DMAP      MØD2      A/X/V,N,PX=0 $
loop      SAVE      PX $
          LABEL     L3 $
          MØD3      W,X,Y/Z $
          REPT      L1,1 $
          MØD4      Z// $
          END       $
```

Assume that MØD2 sets PX < 0 when it is executed. Note that Z is declared APPEND, whereas Y will be saved since it is an internal data block that is to be appended. X is an internal data block that is to be saved since it will only be generated the first time through the loop but is needed as input each time the loop is repeated. W is an internal data block that is generated each time through the loop; therefore, it is not saved.

The following table shows what happens when the above DMAP program is executed. Only modules being executed are shown in the table. Data blocks A and B are assumed to be generated by the Input File Processor, and hence are considered referenced outside of all DMAP loops.

Module being executed	Input status and comments	Output status and comments
MØD1	B-assumed generated by the input file processor	W, Y - generated
CØND	PX is 0	No transfer occurs since PX ≥ 0
MØD2	A-assumed generated by the input file processor	X - generated PX is set < 0
SAVE	PX < 0	The value created above is saved for subsequent use.
MØD3	W, X, Y are all generated at this point	Z - generated
REPT	Loop count is initially set at 1	Transfer to L1 - set loop count to 1-1=0 Status of data blocks at top of loop will be: A, B, Z - generated (referenced outside loop) X, Y - generated (internal data blocks declared saved) W - not generated (internal data block)
MØD1	B - generated	W - generated Y - generated (appended)
CØND	PX is now < 0 due to SAVE	Transfer to L3 occurs
MØD3	W, X, Y - generated	Z - generated (appended)
REPT	Loop count is now 0	No transfer occurs.
MØD4	Z - generated	Output to printer (assumed)
END		Normal termination of problem.

5.2.3.2 The EQUIV Instruction (see Section 5.7)

There are no restrictions on the status of data blocks referenced in an EQUIV instruction. Consider the instruction EQUIV $A,B_1,---,B_N/P$ \$ when $P < 0$. Data blocks $B_1,---,B_N$ take on all the characteristics of data block A including the status of A. This means the status of some B_j can change from purged to generated or not generated.

The EQUIV instruction will unequivalence data blocks when $P \geq 0$. In an unequivalence operation, the status of all secondary data blocks reverts to not generated.

Suppose A, B, and C are all equivalenced and $P \geq 0$. EQUIV A,B/P \$ will break the equivalence between A and B but not between A and C.

Now consider the following situation. Data block B is to be generated by repeatedly executing functional module MØD2. The input to MØD2 is the previous output from MØD2. That is to say, each successive generation of B depends on the previous B generated. The following example shows how the EQUIV instruction is used to solve this problem. Assume parameter BREAK ≥ 0 and parameter LINK < 0.

<u>EXAMPLE</u> of EQUIV instruction.

```
              BEGIN    $
              MØD1     A/B  $
            ( LABEL    L1  $
   DMAP     ) EQUIV    B,BB/BREAK  $
   loop    <  MØD2     B/BB  $
            ) EQUIV    BB,B/LINK  $
            ( REPT     L1,1  $
              MØD3     BB//  $
              END      $
```

The following table shows what happens when the above DMAP program is executed. Only modules being executed are shown in the table.

Module being executed	Input status and comments	Output status and comments
MØD1	A-assumed generated by input processor	B - generated
EQUIV	B will not be equivalenced to BB since BREAK ≥ 0.	No action taken.
MØD2	B-generated	BB - generated
EQUIV	BB and B are not equivalenced. B - generated BB - generated LINK < 0.	B is equivalenced to BB. That is, B assumes all of the characteristics of BB. B and BB then both have the status of generated.
REPT	Loop count is initially 1	Transfer to L1; set loop count to 1-1=0.
EQUIV	B and BB are generated and equivalenced. BREAK ≥ 0.	The equivalence is broken; B - generated, BB - not generated
MØD2	B-generated	BB - generated
EQUIV	BB and B are generated and not equivalenced. LINK < 0.	B equivalenced to BB; B,BB - generated
REPT	Loop count is 0	No transfer occurs.
MØD3	BB - generated	Output to printer (assumed)
END		Normal termination of problem.

Since equivalences are automatically broken between internal files (not declared saved) and files referenced outside the loop, the above DMAP program could be written as follows and the same results achieved.

```
              BEGIN     $
              MØD1      A/B  $
            ( LABEL     L1  $
DMAP        ) MØD2      B/BB  $
loop        ) EQUIV     BB,B/LINK  $
            ( REPT      L1,1  $
              MØD3      B//  $
              END       $
```

Data block BB is now internal; therefore, the instruction EQUIV B,BB/BREAK $ is not needed.

5.2.3.3 The PURGE Instruction (see Section 5.7)

The status of a data block is changed to purged by explicitly or implicitly purging it. A data block is explicitly purged through the PURGE instruction, whereas it is implicitly purged if it is not created by the functional module in which it appears as an output.

The primary purpose of the PURGE instruction is to prepurge data blocks. Prepurging is the explicit purging of a data block prior to its appearance as output from a functional module. Prepurging data blocks allows the NASTRAN executive system to allocate available files more efficiently which decreases problem execution time. The DMAP programmer should look for data blocks that can be prepurged and purge them as soon as it is recognized that they will not be generated.

Sometimes during the execution of a problem it is necessary to generate a data block whose status is purged. This situation can occur both in DMAP looping and in a modified restart situation. In order to generate a data block that is purged it is first necessary to unpurge it (i.e., change its status from purged to not generated). Unpurging is achieved by executing a PURGE instruction which references the purged data block and whose purge parameter is positive.

The PURGE instruction thus has two functions, to unpurge as well as purge data blocks depending on the value of the purge parameter and the status of the referenced data block. The following table shows what action is taken by the PURGE instruction for all combinations of input.

PURGE A/P $		
Status of data block A prior to PURGE	Value of P	Status of Data block A after PURGE
Not generated Not generated	$P \geq 0$ $P < 0$	Not generated (i.e., no action taken) Purged
Generated Generated	$P \geq 0$ $P < 0$	Generated (i.e., no action taken) Purged
Purged Purged	$P \geq 0$ $P < 0$	Not generated (i.e., unpurged) Purged (i.e., no action taken)

The user may wonder why he should not prepurge all data blocks and then unpurge them when necessary in order to really assist the file allocator. One should not do this, since there is a limited amount of space in the table where the status of data blocks is kept. One may overflow this table if too many data blocks are purged at one time. Therefore, only prepurge those data blocks that can truly be prepurged.

EXAMPLE of explicit and implicit purging and prepurging.

```
BEGIN    $
MØD1     IP/A/V,Y,PX/V,Y,PY/V,Y,PB  $
SAVE     PX,PY,PB  $
PURGE    X/PX / Y/PY  $
MØD2     A/B,C,D/V,Y,PB/V,Y,PC  $
SAVE     PC  $
PURGE    C/PC  $
MØD3     B,C,D/E  $
MØD4     E/X,Y,Z  $
MØD5     X,Y,Z//  $
END      $
```

Assume that module MØD1 sets $PX < 0$, $PY \geq 0$ and $PB = 0$. Assume that B is not generated by MØD2 if $PB = 0$. Assume that MØD2 sets $PC < 0$, but does not change PB.

The following table shows what happens when the above DMAP program is executed. Only modules being executed are shown in the table.

Module being executed	Input status and comments	Output status and comments
MØD1	IP-assumed generated by the input file processor	A - generated PX < 0, PY ≥ 0, PB = 0
SAVE	PX < 0, PY ≥ 0, PB = 0	Parameter values are saved for use in subsequent modules.
PURGE	X,Y-not generated PX < 0, PY ≥ 0	X - purged (i.e., prepurged) Y - not generated
MØD2	A - generated; PB = 0	B - purged (i.e., implicitly); C, D - generated; PC < 0.
SAVE	PC < 0	PB value not saved since MØD2 did not reset it.
PURGE	C - generated PC < 0	C - purged
MØD3	B, C - purged D - generated	E - generated
MØD4	E - generated	X - purged; Y - generated; Z - generated
MØD5	X - purged Y, Z - generated	Output to printer (assumed)
END		Normal termination of problem.

<u>EXAMPLE</u> of unpurging.

```
                BEGIN    $
                FILE     X=SAVE/Y=SAVE  $
                FILE     Z=APPEND $
                MØD1     IP/A  $
              / LABEL    L1  $
             |  CØND     L2,NPX  $
             |  PURGE    X/NPX  $
             |  MØD2     A/X,Y/V,Y,PX=0/V,N,NPX=0 $
    DMAP    <   SAVE     PX,NPX $
    loop     |  PURGE    X/PX  $
             |  LABEL    L2  $
             |  MØD3     X,Y/Z  $
              \ REPT     L1,2  $
                MØD4     Z// $
                END      $
```

Assume that MØD2 sets PX<0 and NPX≥0 the first time it is executed. Assume that MØD2 sets PX $\geq$ 0 and NPX < 0 the second time it is executed.

The following table shows what happened when the above DMAP program is executed. Only modules being executed are shown in the table.

Module being executed	Input status and comments	Output status and comments
MØD1	IP-assumed generated by input file processor.	A - generated
CØND	NPX = 0	Jump not executed
PURGE	X - not generated	X - not generated (i.e., no action taken)
MØD2	A - generated	X, Y - generated; PX < 0, NPX ≥ 0
SAVE	PX < 0, NPX ≥ 0	
PURGE	X - generated; PX < 0	X - purged
MØD3	X - purged; Y - generated	Z - generated
REPT	Loop count = 2	Transfer to location L1; Loop count = 1
CØND	NPX ≥ 0	Jump not executed
PURGE	X - purged; NPX ≥ 0	X - not generated (i.e., unpurged)
MØD2	A - generated	X - generated; Y - generated (note old data for Y is lost because Y not Appended); PX ≥ 0, NPX < 0
SAVE	PX ≥ 0, NPX < 0	
PURGE	X - generated; PX ≥ 0	X - generated (i.e., no action taken)
MØD3	X,Y - generated	Z - generated (note new data appended to old because Z declared appended)
REPT	Loop count = 1	Transfer to location L1; Loop count = 0
CØND	NPX < 0	Transfer to location L2
MØD3	X, Y - generated	Z - generated (i.e., appended)
REPT	Loop count = 0	Fall through to next instruction
MØD4	Z - generated	Output to printer (assumed)
END		Normal termination of problem

5.2.3.4 The CHKPNT Instruction (see Section 5.7)

The CHKPNT instruction provides the user with a means for saving data blocks for subsequent restart of his problem with a minimum amount of redundant processing. The following rules will assure the DMAP programmer of the most efficient restart.

1. Checkpoint all output data blocks from every functional module.

2. Checkpoint all data blocks mentioned in a PURGE instruction.

3. Checkpoint all secondary data blocks in an EQUIV instruction. Never checkpoint primary data blocks in an EQUIV instruction.

<u>EXAMPLE</u> of checkpointing.

```
BEGIN  $
MØD1   A/B,C/V,Y,P1/V,Y,P2  $
SAVE   P1,P2  $
CHKPNT B,C  $
PURGE  X,Y/P1 / Z/P2  $
CHKPNT X,Y,Z  $
EQUIV  B,BB/P1 / C,CC,D/P2  $
CHKPNT BB,CC,D  $
  .
  .
  .
END    $
```

In the example the data blocks were checkpointed as soon as possible, which is the most straightforward way, but it required three calls to the checkpoint module, which increases problem execution time. Since checkpointing usually requires a small fraction of the total execution time, it is recommended that the user use the most straightforward method to avoid trouble. The rigid format DMAP sequences have been designed for efficiency and, consequently, they appear more complex than they really are.

5.3 INDEX OF DMAP MODULE DESCRIPTIONS

Descriptions of all nonstructurally oriented modules are contained herein, arranged alphabetically by category as indicated by the lists below. Descriptions for the structurally oriented modules are contained in Section 4 of the Programmer's Manual. They are listed here in order to provide a complete list of all NASTRAN modules. Additional information regarding nonstructurally oriented modules is also given in Section 4 of the Programmer's Manual.

Matrix Operation Modules (15)
(See Section 5.4)

ADD	PARTN
ADD5	SDCMPS
DECØMP	SMPYAD
DIAGONAL	SØLVE
FBS	TRNSP
MERGE	UMERGE
MPYAD	UPARTN
MPY3	

Utility Modules (24)
(See Section 5.5)

CØPY	PARAML
INPUT	PARAMR
INPUTT1	PRTPARM
INPUTT2	SCALAR
LAMX	SEEMAT
MATGPR	SETVAL
MATPRN	SWITCH
MATPRT	TABPCH
ØUTPUT1	TABPRT
ØUTPUT2	TABPT
ØUTPUT3	TIMETEST
PARAM	VEC

User Modules (14)
(See Section 5.6)

DDR	MATGEN
DUMMØD1	MØDA
DUMMØD2	MØDB
DUMMØD3	MØDC
DUMMØD4	ØUTPUT
INPUTT3	ØUTPUT4
INPUTT4	XYPRNPLT

Executive Operation Modules (16)
(See Section 5.7)

BEGIN	FILE
CHKPNT	JUMP
CØMPØFF	LABEL
CØMPØN	PRECHK
CØND	PURGE
END	REPT
EQUIV	SAVE
EXIT	XDMAP

Substructure DMAP ALTERs (22)
(See Section 5.9)

BRECØVER	PLØT
CHECK	RECØVER
CØMBINE	REDUCE
CREDUCE	RENAME
DELETE	RESTØRE
DESTRØY	RUN
DUMP	SØFIN
EDIT	SØFØUT
EQUIV	SØFPRINT
MRECØVER	SØLVE
MREDUCE	SUBSTRUCTURE

Supplementary Functional Modules (2)
(See Section 5.10)

EMA1	GPSPC

1284

Structurally Oriented Functional Modules (113)
(See Section 4 of the Programmer's Manual)

ADR	EQMCK	MRED1	SDR1
AMG	EXIØ	MRED2	SDR2
AMP	FA1	MTRXIN	SDR3
ANISØP	FA2	NRLSUM	SGEN
APD	FLBMG	ØFP	SMA1
BMG	FRLG	ØPTPR1	SMA2
CASE	FRRD	ØPTPR2	SMA3
CASEGEN	FRRD2	PLA1	SMP1
CEAD	GENCØS	PLA2	SMP2
CMRED2	GENPART	PLA3	SØFI
CØMBUGV	GFSMA	PLA4	SØFØ
CØMB1	GI	PLØT	SØFUT
CØMB2	GKAD	PLTMRG	SSGHT
CURV	GKAM	PLTSET	SSG1
CYCT1	GPCYC	PLTTRAN	SSG2
CYCT2	GPFDR	PRØLATE	SSG3
DDAMAT	GPSP	PRTMSG	SSG4
DDAMPG	GPWG	RANDØM	SUBPH1
DDRMM	GP1	RBMG1	TA1
DDR1	GP2	RBMG2	TRAILER
DDR2	GP3	RBMG3	TRD
DESVEL	GP4	RBMG4	TRHT
DPD	GUST	RCØVR	TRLG
DSCHK	IFT	RCØVR3	VDR
DSMG1	LØADPP	READ	XYPLØT
DSMG2	MAGBDY	REDUCE	XYTRAN
EMA	MCE1	RMG	
EMFLD	MCE2	SCE1	
EMG	MØDACC	SDRHT	

In the examples that accompany each description, the following notation is used:

1. Upper case letters and special symbols in the DMAP calling sequence must be punched as shown except for data block names, parameter names, and label names which are symbolic.

2. Lower case letters represent constants whose permissible values are indicated in the descriptive text.

Due to the many possible forms which may be used when writing parameters, a variety of arbitrarily selected forms will be used in the examples. This does not imply that the form used in any example is required or that it is the only acceptable form allowed.

The terms form, type, and precision are used in many functional module descriptions. By form is meant one of the following:

Form	Meaning
1	Square matrix
2	Rectangular matrix
6	Symmetric matrix

INDEX OF DMAP MODULE DESCRIPTIONS

By type is meant one of the following:

Form	Meaning
1	Real, single precision
2	Real, double precision
3	Complex, single precision
4	Complex, double precision

By precision is meant one of the following:

Precision Indicator	Meaning
1	Single precision numbers
2	Double precision numbers

5.4 MATRIX OPERATION MODULES

Module	Basic Operation	Page
ADD	$[X] = a[A] + b[B]$	5.4-2
ADD5	$[X] = a[A] + b[B] + c[C] + d[D] + e[E]$	5.4-3
DECØMP	$[A] \Rightarrow [L][U]$	5.4-4
DIAGØNAL	$[A] \Rightarrow [a_{ii}^{p}]$	5.4-5
FBS	$[X] = \pm([L][U])^{-1}\,[B]$	5.4-6
MERGE	$[A] \Leftarrow \left[\begin{array}{c\|c} A11 & A12 \\ \hline A21 & A22 \end{array}\right]$	5.4-8
MPYAD	$[X] = \pm[A][B] \pm [C]$ or $\pm[A]^T[B] \pm [C]$	5.4-10
MPY3	$[X] = [A]^T[B][A] + [C]$, $[A]^T[B] + [C]$ or $[B][A] + [C]$	5.4-12
PARTN	$[A] \Rightarrow \left[\begin{array}{c\|c} A11 & A12 \\ \hline A21 & A22 \end{array}\right]$	5.4-13
SDCMPS	$[A] \Rightarrow [L][U]$	5.4-16
SMPYAD	$[X] = [A][B][C][D][E] \pm [F]$	5.4-20
SØLVE	$[X] = \pm[A]^{-1}\,[B]$	5.4-22
TRNSP	$[X] = [A]^T$	5.4-24
UMERGE	$\{PHIF\} \Leftarrow \left\{\begin{array}{c} PHIA \\ \hline PHIØ \end{array}\right\}$	5.4-25
UPARTN	$[K_{ii}] = \left[\begin{array}{c\|c} K_{jj} & K_{j\ell} \\ \hline K_{\ell j} & K_{\ell\ell} \end{array}\right]$	5.4-27

I. NAME: ADD (Matrix Add)

II. PURPØSE: To compute [X] = a[A] + b[B] where a and b are scale factors.

III. DMAP CALLING SEQUENCE:

```
ADD  A,B / X / C,Y,ALPHA=(1.0,2.0) / C,Y,BETA=(3.0,4.0) $
```

IV. INPUT DATA BLØCKS:

A - Any matrix

B - Any matrix

Note: [A] and/or [B] may be purged, in which case the corresponding term in the matrix sum will be assumed null. The input data blocks must be unique.

V. ØUTPUT DATA BLØCKS:

X - matrix.

The type of [X] is maximum of the types of [A], [B], a, b. The size of [X] is the size of [A] if [A] is present. Otherwise it is that of [B].

Note: [X] cannot be purged.

VI. PARAMETERS:

ALPHA - Input-complex-single precision, default = (1.0, 0.0). This is a, the scalar multiplier for [A].

BETA - Input-complex-single precision, default = (1.0, 0.0). This is b, the scalar multiplier for [B].

Note: If Im(ALPHA) or Im(BETA) = 0.0 the corresponding parameter will be considered real.

I. NAME: ADD5 (Matrix Add)

II. PURPØSE: To compute [X] = a[A] + b[B] + c[C] + d[D] + e[E] where a, b, c, d and e are scale factors.

III. DMAP CALLING SEQUENCE:

```
ADD5  A,B,C,D,E / X / C,Y,ALPHA=(1.0,2.0) / C,Y,BETA=(3.0,4.0) / C,Y,GAMMA=(5.0,6.0) /
                      C,Y,DELTA=(7.0,8.0) / C,Y,EPSLN=(9.0,1.0) $
```

IV. INPUT DATA BLØCKS:

A, B, C, D, and E must be distinct matrices.

Note: Any of the matrices may be purged, in which case the corresponding term in the matrix sum will be assumed null. The input data blocks must be unique.

V. ØUTPUT DATA BLØCKS:

X - matrix.

The type of [X] is maximum of the types of A, B, C, D, E, a, b, c, d, e. The size of [X] is the size of the first nonpurged input.

Note: [X] cannot be purged.

VI. PARAMETERS:

ALPHA - Input-complex-single precision, default = (1.0, 0.0). This is a, the scalar multiplier for [A].

BETA - Input-complex-single precision, default = (1.0, 0.0). This is b, the scalar multiplier for [B].

GAMMA - Input-complex-single precision, default = (1.0, 0.0). This is c, the scalar multiplier for [C].

DELTA - Input-complex-single precision, default = (1.0, 0.0). This is d, the scalar multiplier for [D].

EPSLN - Input-complex-single precision, default = (1.0, 0.0). This is e, the scalar multiplier for [E].

Note: If Im(ALPHA), Im(BETA), Im(GAMMA), Im(DELTA), or Im(EPSLN) = 0.0, the corresponding parameter will be considered real.

I. DECØMP (Matrix Decomposition)

II. PURPØSE: To decompose a square matrix [A] into upper and lower triangular factors [U] and [L] .

$$[A] \Rightarrow [L][U]$$

III. DMAP CALLING SEQUENCE:

```
DECØMP  A / L,U / V,Y,KSYM / V,Y,CHØLSKY / V,N,MINDIAG / V,N,DET / V,N,PØWER / V,N,SING $
```

IV. INPUT DATA BLØCKS:

A - A square matrix

V. ØUTPUT DATA BLØCKS:

L - Nonstandard lower triangular factor of [A].

U - Nonstandard upper triangular factor of [A].

VI. PARAMETERS:

KSYM - Input-integer, default = 0. 1, use symmetric decomposition. 0, use unsymmetric decomposition.

CHØLSKY - Input-integer, default = 0. 1, use Cholesky decomposition - matrix must be positive definite. 0, do not use Cholesky decomposition.

MINDIAG - Output-real double precision, default = 0.0D0. The minimum diagonal term of [U].

DET - Output-complex single precision, default = 0.0D0. The scaled value of the determinant of [A].

PØWER - Output-integer, default = 0. Integer PØWER of 10 by which DET should be multiplied to obtain the determinant of [A].

SING - Output-integer, default = 0. SING is set to -1 if [A] is singular.

VII. REMARKS:

1. Non-standard triangular factor matrix data blocks are used to improve the efficiency of the back substitution process in module FBS. The format of these data blocks is given in Section 2 of the Programmer's Manual.

2. The matrix manipulating utility modules should be cautiously employed when dealing with non-standard matrix data blocks.

3. If the CHØLSKY option is selected, the resulting factor (which will be written as [U]) cannot be input to FBS.

4. Variable parameters output from functional modules must be SAVEd if they are to be subsequently used. See the Executive Module SAVE description.

I. NAME: DIAGØNAL (Strip diagonal from matrix)

II. PURPOSE: To remove the real part of the diagonal from a matrix, raise each term to a specified power, and output a column vector, a square symmetric matrix or a diagonal matrix.

III. DMAP CALLING SEQUENCE:

```
DIAGØNAL A/B/C,Y,ØPT=CØLUMN/V,Y,PØWER=1. $
```

IV. INPUT DATA BLOCKS:

A - can be any square or diagonal matrix.

V. OUTPUT DATA BLOCKS:

B - is either a real column vector, a symmetric matrix or a diagonal matrix containing the diagonal of A.

VI. PARAMETERS:

ØPT - Input-BCD, default=CØLUMN
= CØLUMN - produces column vector output (labeled as a general rectangular matrix)
= SQUARE - produces square matrix (labeled as a symmetric matrix)
= DIAGØNAL - produces diagonal matrix (labeled as a diagonal matrix)

PØWER - Input-real single precision, default = 1.0. Exponent to which the real part of each diagonal element is raised.

VII. REMARKS:

1. The module checks for special cases of PØWER = 0.0, 0.5, 1.0 and 2.0.
2. The precision of the output matrix matches the precision of the input matrix.

DIRECT MATRIX ABSTRACTION

I. NAME: FBS (Matrix Forward-Backward Substitution)

II. PURPOSE: To solve the matrix equation [L][U][X] = ± [B] where [L] and [U] are the lower and upper triangular factors of a matrix previously obtained via Functional Module DECØMP.

III. DMAP CALLING SEQUENCE:

FBS L,U,B / X / V,Y,SYM / V,Y,SIGN / V,Y,PREC / V,Y,TYPE $

IV. INPUT DATA BLOCKS:

L - Nonstandard lower triangular factor
U - Nonstandard upper triangular factor
B - Rectangular matrix

V. OUTPUT DATA BLOCKS:

X - Rectangular matrix having the same dimensions as [B].

VI. PARAMETERS:

SYM - Input-integer-default = 0
- 1 - matrix [L][U] is symmetric
- -1 - matrix [L][U] is unsymmetric
- 0 - reset to 1 or -1 depending upon [U] being purged or not respectively.

- Output-integer: SYM used

SIGN - Input-integer-default = 1.
- 1 - solve [L][U][X] = [B]
- -1 - solve [L][U][X] = -[B]

PREC - Input-integer-default = 0
- 1 - use single precision arithmetic
- 2 - use double precision arithmetic
- 0 - logical choice based on input and system precision flag

- Output-integer: Precision used.

TYPE - Input-integer-default = 0
- 1 - output type of matrix [X] is real single precision
- 2 - output type of matrix [X] is real double precision
- 3 - output type of matrix [X] is complex single precision
- 4 - output type of matrix [X] is complex double precision
- 0 - logical choice based on input matrices

- Output-integer: TYPE used.

VII. REMARKS:

1. Non-standard triangular factor matrix data blocks are used to improve the efficiency of the back substitution process. The format of these data blocks is given in Section 2 of the Programmer's Manual.

2. The matrix manipulating utility modules should be cautiously employed when dealing with non-standard matrix data blocks.

I. NAME: MERGE (Matrix Merge)

II. PURPØSE: To form the matrix [A] from its partitions:

$$[A] \Longleftarrow \begin{array}{ccc} & \longleftarrow CP \longrightarrow & \\ RP\updownarrow & \left[\begin{array}{c|c} A11 & A12 \\ \hline A21 & A22 \end{array}\right] & \begin{array}{l} = 0 \\ \neq 0 \end{array} \\ & \begin{array}{cc} = 0 & \neq 0 \end{array} & \end{array}$$

III. DMAP CALLING SEQUENCE:

MERGE A11,A21,A12,A22,CP,RP / A / V,Y,SYM / V,Y,TYPE / V,Y,FØRM $

IV. INPUT DATA BLØCKS:

A11 - Matrix

A21 - Matrix

A12 - Matrix

A22 - Matrix

CP - Column partitioning vector (see below) - Single precision column vector.

RP - Row partitioning vector (see below) - Single precision column vector.

Notes:

1. Any or all of [A11], [A12], [A21], [A22] can be purged. When all are purged this implies [A] = [0].
2. {RP} and {CP} may not both be purged.
3. See Remarks for meaning when either of {RP} or {CP} is purged.
4. [A11], [A12], [A21], [A22] must be unique matrices.

V. ØUTPUT DATA BLØCKS:

A - merged matrix from [A11], [A12], [A21], [A22]

Notes: [A] cannot be purged.

VI. PARAMETERS:

SYM - Input-integer, default = -1. SYM < 0, {CP} is used for {RP}. SYM $\geq$ 0, {CP} and {RP} are distinct.

TYPE - Input-integer, default = 0. Type of [A] - see Remark 4

FØRM - Input-integer, default = 0. Form of [A] - see Remark 3

VII. REMARKS:

1. MERGE is the inverse of PARTN in the sense that if [A11], [A12], [A21], [A22] were produced by PARTN using {RP}, {CP}, FØRM, SYM, and TYPE from [A], MERGE will produce [A]. See PARTN for options on {RP}, {CP} and SYM.
2. All input data blocks must be distinct.
3. When FØRM = 0, a compatible matrix [A] results as shown in the following table:

		Form of A22		
		Square	Rectangular	Symmetric
Form of A11	Square	Square	Rectangular	Rectangular
	Rectangular	Rectangular	Rectangular	Rectangular
	Symmetric	Rectangular	Rectangular	Symmetric

4. If TYPE = 0, the type of the output matrix will be the maximum type of [A11], [A12], [A21] and [A22].

DIRECT MATRIX ABSTRACTION

I. NAME: MPYAD (Matrix Multiply and Add)

II. PURPOSE: MPYAD performs the multiplication of two matrices and, optionally, addition of a third matrix to the product. By means of parameters, the user may compute $\pm$ [A][B] $\pm$ [C] = [X], or $\pm$ $[A]^T$[B] $\pm$ [C] = [X].

III. DMAP CALLING SEQUENCE:

```
MPYAD    A,B,C / X / V,N,T / V,N,SIGNAB / V,N,SIGNC / V,N,TYPEX $
```

IV. INPUT DATA BLOCKS:

A - Left hand matrix in the matrix product [A][B]
B - Right hand matrix in the matrix product [A][B]
C - Matrix to be added to [A][B]

Notes:

1. If no matrix is to be added, [C] must be purged.
2. [A], [B], [C] must be physically different data blocks.
3. [A] and [B] must not be purged.
4. [A], [B], and [C] must be conformable. This condition is checked by MPYAD.

V. OUTPUT DATA BLOCKS:

X - Matrix resulting from the MPYAD operation.

Note: [X] may not be purged.

VI. PARAMETERS:

T - Integer-input, no default. T = { 1 - perform $[A]^T$[B]; 0 - perform [A][B] }

SIGNAB - Integer-input, default = 1. SIGNAB = { +1 - perform [A][B]; 0 - omit [A][B]; -1 - perform -[A][B] }

SIGNC - Integer-input, default = 1. SIGNC = { +1 - add [C]; 0 - omit [C]; -1 - subtract [C] }

TYPEX - Input-integer, default = 0.
- 0 - logical choice based on input
- 1 - output type of matrix X is real single precision
- 2 - output type of matrix X is real double precision
- 3 - output type of matrix X is complex single precision
- 4 - output type of matrix X is complex double precision

- Output-integer TYPEX used.

VII. EXAMPLES:

1. [X] = [A][B]+[C] ([X] see notes)
   MPYAD A,B,C / X / C,N,0 $

2. [X] = $[A]^T$[B]-[C] ([X] real single-precision)
   MPYAD A,B,C / X / C,N,1 / C,N,1 / C,N,-1 / C,N,1 $

3. [X] = -[A][B] ([X] see notes)
   MPYAD A,B, / X / C,N,0 / C,N,-1 $

Notes: The precision of [X] is determined from the input matrices in that if anyone of these matrices is specified as double precision, then [X] will also be double precision. If the precision for the input matrices is not specified, the precision of the system flag will be used.

I. NAME: MPY3 (Triple Matrix Multiply)

II. PURPOSE: To perform the matrix product $[X]=[A]^T[B][A] + [C]$, $[X]=[A]^T[B]+[C]$ or $[X]=[B][A] + [C]$ for sparse A matrix and dense B matrix.

III. DMAP CALLING SEQUENCE:

```
MPY3 A,B,C /X/ V,N,CØDE / V,N,PREC $
```

IV. INPUT DATA BLOCKS:

A - Matrix[A]
B - Matrix[B]
C - Matrix[C]

Notes:

1. If no matrix is to be added, [C] must be purged.
2. [A], [B] and [C] must be physically different data blocks.
3. [A] and [B] must not be purged.
4. [A], [B] and [C] must be conformable.

V. OUTPUT DATA BLOCKS:

X - Matrix resulting from the triple matrix multiplication.

Note: [X] may not be purged.

VI. PARAMETERS:

CØDE - Input-integer, default = 0. If CØDE = 0, $A^TBA + C$ is performed. If CØDE = 1, $A^TB + C$ is performed via MPYAD. If CØDE = 2, BA + C is performed.

PREC - Input-integer, default = 0. If PREC = 0, output precision is the logical choice based on input. If PREC = 1, output is in real single precision. If PREC = 2, output is in real double precision.

VII. REMARKS:

1. See Section 4.157 of the Programmer's Manual for a detailed description of the MPY3 module.

I. NAME: PARTN (Matrix Partition)

II. PURPØSE: To partition [A] into [A11], [A12], [A21] and [A22]:

$$
\begin{array}{ccc}
 & \xleftrightarrow{\quad CP \quad} & \\
[A] \Longrightarrow RP\updownarrow & \left[\begin{array}{c|c} A11 & A12 \\ \hline A21 & A22 \end{array}\right] & \begin{array}{l} = 0 \\ \neq 0 \end{array} \\
 & \begin{array}{cc} = 0 & \neq 0 \end{array} &
\end{array}
$$

III. DMAP CALLING SEQUENCE:

PARTN A,CP,RP / A11,A21,A12,A22 / V,Y,SYM / V,Y,TYPE / V,Y,F11 / V,Y,F21 / V,Y,F12 / V,Y,F22 $

IV. INPUT DATA BLØCKS:

A - Matrix to be partitioned.

CP - Column partitioning vector - single precision column vector.

RP - Row partitioning vector - single precision column vector.

V. ØUTPUT DATA BLØCKS:

A11 - Upper left partition of [A]

A21 - Lower left partition of [A]

A12 - Upper right partition of [A]

A22 - Lower right partition of [A]

Notes: 1. Any or all output data blocks may be purged.
2. For size of outputs see METHØD section below.

VI. PARAMETERS:

SYM - Input-integer, default = -1. SYM chooses between a symmetric partition and one unsymmetric partition. If SYM < 0, {CP} is used as {RP}. If SYM $\geq$ 0, {CP} and {RP} are distinct.

TYPE - Input-integer, default = 0. Type of output matrices - see Remark 8

F11 - Input-integer, default = 0. Form of [A11].
F21 - Input-integer, default = 0. Form of [A21].
F12 - Input-integer, default = 0. Form of [A12].
F22 - Input-integer, default = 0. Form of [A22].
See Remark 7

VII. METHØD:

Let NC = number of nonzero terms in {CP}.

Let NR = number of nonzero terms in {RP}.

Let NRØWA = number of rows in [A].

Let NCØLA = number of columns in [A].

Case 1 {CP} purged and SYM $\geq$ 0.

[A11] is a (NRØWA-NR) by NCØLA matrix.

[A21] is a NR by NCØLA matrix.

[A12] is not written.

[A22] is not written.

$$[A] \rightarrow \left[\begin{array}{c} A11 \\ \hline A21 \end{array}\right]$$

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CASE 2 {RP} purged and SYM $\geq$ 0

[A11] is a NRØWA by (NCØLA - NC) matrix.

[A21] is not written.

[A12] is a NRØWA by NC matrix.

[A22] is not written.

$$[A] \rightarrow [A11 \mid A12]$$

CASE 3 SYM < 0 ({RP} must be purged)

[A11] is a (NRØWA - NC) by (NCØLA - NC) matrix.

[A21] is a NC by (NCØLA - NC) matrix.

[A12] is a (NRØWA - NC) by NC matrix.

[A22] is a NC by NC matrix.

$$[A] \rightarrow \left[\begin{array}{c|c} A11 & A12 \\ \hline A21 & A22 \end{array}\right]$$

CASE 4 neither {CP} nor {RP} purged and SYM $\geq$ 0

[A11] is a (NRØWA - NR) by (NCØLA - NC) matrix.

[A21] is a NR by (NCØLA - NC) matrix.

[A12] is a (NRØWA - NR) by NC matrix.

[A22] is a NR by NC matrix.

$$[A] \rightarrow \left[\begin{array}{c|c} A11 & A12 \\ \hline A21 & A22 \end{array}\right]$$

VIII. REMARKS:

1. If [A] is purged, PARTN will cause all output data blocks to be purged.
2. If {CP} is purged, [A] is partitioned as follows:

$$[A] \Rightarrow \left[\begin{array}{c} A11 \\ \hline A21 \end{array}\right].$$

3. If {RP} is purged and SYM $\geq$ 0, [A] is partitioned as follows:

$$[A] \Rightarrow [A11 \mid A12]$$

4. If {RP} is purged and SYM < 0, [A] is partitioned as follows:

$$[A] \Rightarrow \left[\begin{array}{c|c} A11 & A12 \\ \hline A21 & A22 \end{array}\right].$$

where {CP} is used as both the row and column partitioner.

5. {RP} and {CP} cannot both be purged.
6.

$$[A] \Rightarrow \left[\begin{array}{c|c} A11 & A12 \\ \hline A21 & A22 \end{array}\right]$$

Let [A] be a m by n order matrix.

Let {CP} be a n order column vector containing q zero elements.

Let {RP} be a m order column vector containing p zero element.

Partition [A11] will consist of all elements A_{ij} of [A] for which $CP_j = RP_i = 0$ in the same order as they appear in [A].

Partition [A12] will consist of all elements A_{ij} of [A] for which $CP_j \neq 0$ and $RP_i = 0$ in the same order as they appear in [A].

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Partition [A21] will consist of all elements A_{ij} or [A] for which $CP_j = 0$ and $RP_i \neq 0$ in the same order as they appear in [A].

Partition [A22] will consist of all elements A_{ij} of [A] for which $CP_j \neq 0$ and $RP_i \neq 0$ in the same order as they appear in [A].

7. If the defaults for F11, F21, F12 or F22 are used, the corresponding matrix will be output with a compatible form entered in the trailer.

8. If TYPE = 0, the type of the output matrices will be the type of the input matrix [A].

IX. EXAMPLES:

1. Let [A], {CP} and {RP} be defined as follows:

$$[A] = \begin{bmatrix} 1.0 & 2.0 & 3.0 & 4.0 \\ 5.0 & 6.0 & 7.0 & 8.0 \\ 9.0 & 10.0 & 11.0 & 12.0 \end{bmatrix}, \quad \{CP\} = \begin{Bmatrix} 1.0 \\ 0.0 \\ 1.0 \\ 1.0 \end{Bmatrix}, \quad \{RP\} = \begin{Bmatrix} 0.0 \\ 0.0 \\ 1.0 \end{Bmatrix}$$

Then, the DMAP instruction

```
PARTN  A,CP,RP / A11,A21,A12,A22 / C,N,1 $
```

will create the real double precision matrices

$$[A11] = \begin{bmatrix} 2.0 \\ 6.0 \end{bmatrix}, \ F11 = 2 \qquad [A12] = \begin{bmatrix} 1.0 & 3.0 & 4.0 \\ 5.0 & 7.0 & 8.0 \end{bmatrix}, \ F12 = 2$$

$$[A21] = [10.0], \ F21 = 1 \qquad [A22] = [9.0 \quad 11.0 \quad 12.0], \ F22 = 2$$

2. If, in Example 1, the DMAP instruction were written as

```
PARTN  A,CP, / A11,A21,A12,A22 / C,N,1 $
```

the resulting matrices would be

$$[A11] = \begin{bmatrix} 2.0 \\ 6.0 \\ 10.0 \end{bmatrix} \qquad [A12] = \begin{bmatrix} 1.0 & 3.0 & 4.0 \\ 5.0 & 7.0 & 8.0 \\ 9.0 & 11.0 & 12.0 \end{bmatrix}$$

[A21] = purged [A22] = purged

3. If, in Example 1, the DMAP instruction were written as

```
PARTN  A,,RP / A11,A21,A12,A22 / C,N,1 $
```

the resulting matrices would be

$$[A11] = \begin{bmatrix} 1.0 & 2.0 & 3.0 & 4.0 \\ 5.0 & 6.0 & 7.0 & 8.0 \end{bmatrix} \qquad [A12] = \text{purged}$$

$$[A21] = [9.0 \quad 10.0 \quad 11.0 \quad 12.0] \qquad [A22] = \text{purged}$$

DIRECT MATRIX ABSTRACTION

I. NAME: SDCMPS (Symmetric Decomposition)

II. PURPOSE: To decompose a matrix [A] into upper and lower triangular factors [U] and [L].

$$[A] \Rightarrow [L][U] .$$

Badly conditioned matrix columns for symmetric real matrices are identified in external identification numbers. Various user exit controls for error conditions are available.

III. DMAP CALLING SEQUENCE:

```
SDCMPS  USET,GPL,SIL,A / L,U / V,Y,SYM / V,Y,DIAGCK / V,Y,DIAGET / V,Y,PDEFCK / V,N,SING /
                         V,Y,SET / V,Y,CHØLSKY / V,N,DET / V,N,MINDIA / V,N,PØWER /
                         V,Y,SUBNAM $
```

IV. INPUT DATA BLOCKS:

USET - Displacement Set Definition Table

GPL - Grid Point List

SIL - Scalar Index List

A - A real symmetric matrix (may not be purged)

Note: Error conditions will be identified by column number if USET, GPL, or SIL are purged for non-substructuring problems.

V. OUTPUT DATA BLOCKS:

L - Lower triangular factor of [A]

U - Upper triangular factor of [A]

VI. PARAMETERS:

SYM - Input, integer, default = 0. 1, use symmetric decomposition. -1, use unsymmetric decomposition. 0, use decomposition based on input matrix form.

DIAGCK - Input, integer, default = 0. Diagonal singularity or nonconservative column exit flag.

- = 0 - nonfatal messages for $e_s > T_s$ (see DIAGET and Remark 6 for definitions).
- > 0 - a maximum of DIAGCK messages for $e_s > T_s$ before aborting decomposition prior to completion.
- < 0 - no check of e_s.

DIAGET - Input, integer, default = 20. Diagonal singularity error tolerance. Used in conjunction with DIAGCK. A message is issued if the error, $e_s > T_s = 2^{-n}$, where n = DIAGET.

PDEFCK - Input, integer, default = 0. Positive definite exit flag.

- = 0 - nonfatal messages are issued for $D_{ii} < 0.0$ and fatal messages are issued for $D_{ii} = 0.0$.
- > 0 - a maximum of PDEFCK fatal messages for all $D_{ii} \leq 0.0$ are issued before aborting decomposition <u>prior</u> to completion.
- < 0 - no check for $D_{ii} < 0.0$. If $D_{ii} = 0.0$, absolute value of PDEFCK messages are issued before aborting deocmposition <u>prior</u> to completion.

SING - Output, integer, no default. SING is set to -1 if [A] is singular, 0 if not positive definite, and 1 otherwise, in the given order.

SET - Input, BCD, default = L. The displacement set to which [A] belongs.

CHØLSKY - Input, integer, default = 0. Cholesky decomposition is used if the value is 1 (matrix must be positive definite); Cholesky decomposition is not used for values other than 1.

DET - Output, real single precision, default = 0.0. The scaled value of the determinant of [A].

MINDIA - Output, double precision, default = 0.0D0. Minimum diagonal of [U].

PØWER - Output, integer, default = 0. Integer power of 10 by which DET should be multiplied to obtain the determinant of [A].

SUBNAM - Input, BCD, default = NØNE. Name of substructure being solved. Not necessary unless this is a substructuring problem.

VII. REMARKS:

1. Non-standard triangular factor matrix data blocks are used to improve the efficiency of the back substitution process in module FBS. The format of these data blocks is given in Section 2 of the Programmer's Manual.

2. If the CHØLSKY option is selected, the resulting factor (which will be written as [U]) cannot be input to FBS.

3. Upon finding a zero diagonal (D_{ii}) on the decomposed matrix a value of 1.0 is substituted for the diagonal term if decomposition is to proceed. However, the fatal error flag is always set in this case.

4. All zero columns on the input matrix cause fatal messages and decomposition is not attempted. If a system error occurs, a null column might result during decomposition in which case the column is labeled as a "Bad Column" and the decomposition is aborted.

5. A nonpositive definite matrix (decomposed diagonal element less than zero) causes the absolute value to be substituted only with the Cholesky option and if decomposition is to be continued.

6. The diagonal singularity test is,

$$e_s = \frac{2^{1-p}}{|D_{ii}/A_{ii}|} ,$$

where p is the number of bits in the mantissa (machine dependent), D_{ii} is the i^{th} diagonal term of the decomposed matrix, and A_{ii} is the i^{th} diagonal term of the input matrix, [A].

7. All matrix messages give the input and decomposed diagonal value except for situations where the input matrix is in error (e.g., the matrix is classified as rectangular or has a null column).

8. Nonconservative columns (identified by $D_{ii} > 1.001 * A_{ii}$) are identified.

9. Variable parameters output from functional modules must be SAVEd if they are to be subsequently used. See Executive Module SAVE instruction.

10. Setting MØDCØM(1) to -1 on the NASTRAN card (see Section 2.1) allows the time and core estimates to be made without actually doing the decomposition. Absolute values greater than 1 replace the variable CLØSE documented in Section 3.5.14.4 of the Programmer's Manual.

VIII. EXAMPLES:

1. To use the SDCMPS module in a static analysis (Rigid Format 1), modules SMP1 and RBMG2 must be removed. For this case, the required ALTERs are as follows:

```
ALTER     n1 $ (where n1 = DMAP statement number of LABEL LBL4)
PARAM     //*PREC*/MPREC $
ALTER     n2, [illegible] $ (where n2 = DMAP statement number of the SMP1 module)
VEC       USET/V/*F*/*Ø*/*A* $
PARTN     KFF,V,/KØØ,,KØA,KAAB $
SDCMPS    USET,GPL,SIL,KØØ/LØØ,/C,Y,SYM=0/C,Y,DIAGCK=0/C,Y,DIAGET=20/
          C,Y,PDEFCK=0/S,N,SINGØ/*Ø*/0/S,N,DETØ/S,N,MINDIAØ/
          S,N,PØWERØ $
CØND      LSING,SINGØ $
FBS       LØØ,,KØA/GØ/1/-1 $
MPYAD     KØA,GØ,KAAB/KAA/1/1/1/MPREC $
ALTER     n3,n3 $ (where n3 = DMAP statement number of the RBMG2 module)
SDCMPS    USET,GPL,SIL,KLL/LLL,/C,Y,SYM=0/C,Y,DIAGCK=0/C,Y,DIAGET=20/
          C,Y,PDEFCK=0/S,N,SINGL/*L*/0/S,N,DETL/S,N,MINDIAL/
          S,N,PØWERL $
CØND      LSING,SINGL $
ALTER     n4 $ (where n4 = DMAP statement number of CØND FINIS, CØUNT)
LABEL     LSING $
PRTPARM   //0/*SINGØ* $
PRTPARM   //0/*SINGL* $
PRTPARM   //-1/*DMAP* $
ENDALTER  $
```

The input parameters SYM, DIAGCK, DIAGET and PDEFCK may be changed from the values illustrated above by either using the form /C,N,i/ or by including a PARAM bulk data card with a different value.

2. To use the SDCMPS module in a real eigenvalue analysis (Rigid Format 3), modules SMP1 and RBMG2 must be removed. For this case, the required ALTERs are as follows:

```
ALTER     n1,n1 $ (Where n1 = DMAP statement number of the SMP1 module)
VEC       USET/V/*F*/*Ø*/*A* $
PARTN     KFF,V,/KØØ,,KØA,KAAB
```

```
SDCMPS    USET,GPL,SIL,KØØ/LØØ,UØØ/C,Y,SYM=0/C,Y,DIAGCK=0/C,Y,DIAGET=20/
          C,Y,PDEFCK=0/S,N,SINGØ/*Ø*/0/S,N,DETØ/S,N,MINDIAØ/
          S,N,PØWERØ $
CØND      LSING,SINGØ $
FBS       LØØ,UØØ,KØA/GØ/1/-1 $
MPYAD     KØA,GØ,KAAB/KAA/1 $
ALTER     n2,n2 $ (where n2 = DMAP statement number of the RBMG2 module)
SDCMPS    USET,GPL,SIL,KLL/LLL,/C,Y,SYM=0/C,Y,DIAGCK=0/C,Y,DIAGET=20/
          C,Y,PDEFCK=0/S,N,SINGL/*L*/0/S,N,DETL/S,N,MINDIAL/
          S,N,PØWERL $
CØND      LSING,SINGL $
ALTER     n3 $ (where n3 = DMAP statement number of LABEL P2)
LABEL     LSING $
PRTPARM   //0/*SINGØ* $
PRTPARM   //0/*SINGL* $
PRTPARM   //-1/*DMAP* $
ENDALTER  $
```

The input parameters SYM, DIAGCK, DIAGET and PDEFCK may be changed from the values illustrated above as indicated under Example 1.

I. NAME: SMPYAD (Matrix Series Multiply and Add)

II. PURPOSE: To multiply a series of matrices together and, optionally, add another matrix to the product:

$$[X] = [A][B][C][D][E] \pm [F] .$$

III. DMAP CALLING SEQUENCE:

```
SMPYAD  A,B,C,D,E,F / X / C,N,n / V,N,SIGNX / V,N,SIGNF / V,N,PX / V,N,TA /
        V,N,TB / V,N,TC / V,N,TD $
```

IV. INPUT DATA BLOCKS:

A, B, C, D, E - Up to 5 matrices to be multiplied together, from left to right.

F - Matrix to be added to the above product.

Notes:

1. If one of the five multiplication matrices is required in the product (see parameter n below) and is purged, the entire calculation is skipped.
2. If the [F] matrix is purged, no matrix will be added to the product.
3. The input matrices must be conformable. This condition is checked by SMPYAD.

V. OUTPUT DATA BLOCKS:

X - Resultant matrix (may not be pre-purged).

VI. PARAMETERS:

1. n = number of matrices involved in the product, counting from the left (integer, input)
2. SIGNX = sign of the product matrix (e.g., [A][B][C][D][E])
   = 1 for plus, -1 for minus (integer, input)
3. SIGNF = sign of the matrix to be added to the product matrix (integer, input)
   = 1 for plus, -1 for minus
4. PX = output precision of the final result (integer, input)
   = 1 for single-precision, 2 for double-precision, 0 logical choice based on input matrices.
5. TA, TB, TC, TD = transpose indicators for the [A],[B],[C], and [D] matrices (1 if transposed matrix to be used in the product; 0 if untransposed) - (integer, input)

Note:

All the parameters except n have default values as follows:

SIGNX = 1 (sign of product is plus)

SIGNF = 1 (sign of added matrix is plus)

PX = 0 (logical choice based on input matrices)

TA, TB, TC, TD = 0 (use untransposed [A],[B],[C], and [D] matrices in the product) (the number of transpose indicators required is one less than the number of matrices in the product. The last matrix in the product cannot be transposed.)

VII. METHOD:

The method is the same as for the MPYAD module with the following additional remarks:

1. None of the matrices may be diagonal.

2. Except for the final product, all intermediate matrix products are generated in double-precision.

3. The matrices are post-multiplied together from right-to-left, i.e., the first product calculated is the product of matrix n-1 and matrix n.

VIII. EXAMPLES:

1. To compute $[X] = [A][B]^T[C]-[F]$, use

```
SMPYAD   A,B,C,,,F / X / C,N,3 / C,N,1 / C,N,-1 / C,N,0 / C,N,0 / C,N,1 $
```

2. To compute $[Z] = -[U]^T[V]^T[W]^T[X]^T[Y]$, use

```
SMPYAD   U,V,W,X,Y, / Z / C,N,5 / C,N,-1 / C,N,0 / C,N,0 / C,N,1 / C,N,1 /
         C,N,1 / C,N,1 $
```

I. NAME: SØLVE (Linear System Solver)

II. PURPOSE: To solve the Matrix Equation

$$[A][X] = \pm [B]$$

III. DMAP CALLING SEQUENCE:

```
SØLVE  A,B / X / V,Y,SYM / V,Y,SIGN / V,Y,PREC / V,Y,TYPE $
```

IV. INPUT DATA BLOCKS:

A - square real or complex matrix

B - rectangular real or complex matrix (if purged, the identity matrix is assumed).

V. OUTPUT DATA BLOCKS:

X - A rectangular matrix

Note: A standard matrix trailer will be written, identifying [X] as a rectangular matrix with the same dimensions as [B] and the type specified.

VI. PARAMETERS:

SYM - Input-integer, default = 0
- -1 - use unsymmetric decomposition
- 1 - use symmetric decomposition
- 0 - logical choice based on input matrices

- Output-integer: SYM used.

SIGN - Input-integer, default = 1
- 1 - solve [A][X] = [B]
- -1 - solve [A][X] = -[B]

PREC - Input-integer, default = 0
- 0 - logical choice based on input
- 1 - use single precision arithmetic
- 2 - use double precision arithmetic

- Output-integer: PREC used.

TYPE - Input-integer, default = 0

- 0 - logical choice based on input
- 1 - output type of matrix [X] is real single precision
- 2 - output type of matrix [X] is real double precision
- 3 - output type of matrix [X] is complex single precision
- 4 - output type of matrix [X] is complex double precision

- Output-integer TYPE used.

VII. METHOD:

Depending on the SYM flag and the type of [A], one of subroutines SDCØMP, DECØMP, or CDCØMP is called to form [A] = [L][U].

One of FBS or GFBS is then called to solve [L][Y] = $\pm$ [B] and [U][X] = [Y], as appropriate.

I. NAME: TRNSP (Matrix Transpose)

II. PURPØSE: To form $[A]^T$ given [A].

III. DMAP CALLING SEQUENCE:

TRNSP A/X $

IV. INPUT DATA BLØCKS:

A - Any matrix data block.

Note: If [A] is purged, TRNSP will cause [X] to be purged.

V. ØUTPUT DATA BLØCKS:

X - The matrix transpose of [A]

Note: [X] cannot be purged.

VI. PARAMETERS: None.

VII. REMARKS:

1. Transposition of large full matrices is very expensive and should be avoided if possible (see Section 2.1.4 of the Theoretical Manual).

2. TRNSP currently uses an algorithm which assumes that the matrix is dense. This algorithm is extremely inefficient for sparse matrices. Sparse matrices should be transposed by using MPYAD.

I. NAME: UMERGE (Merges two matrices based on USET)

II. PURPOSE: To merge two column matrices (such as load vectors or displacement vectors) into a single matrix.

III. DMAP CALLING SEQUENCE:

UMERGE USET,PHIA,PHIØ / PHIF / V,N,MAJØR=F / V,N,SUBO=A / V,N,SUB1=L $

IV. INPUT DATA BLOCKS:

USET - displacement set definitions

$\left.\begin{array}{l}\text{PHIA}\\ \text{PHIØ}\end{array}\right\}$ any matrices

Note: 1. The set definitions may be USET (statics), USETD (dynamics), HUSET (heat transfer), or USETA (aeroelastic).

2. USET, USETD, HUSET, or USETA may not be purged.

3. PHIA or PHIØ may be purged in which case their respective elements will be zero.

4. PHIA, PHIØ and PHIF must be related by the following matrix equation

$$\left\{\frac{\text{PHIA}}{\text{PHIØ}}\right\} \Longrightarrow \left\{\text{PHIF}\right\}$$

V. OUTPUT DATA BLOCKS:

PHIF - matrix

Note: PHIF must not be purged.

VI. PARAMETERS:

MAJØR - BCD value from table below (Input, no default)

SUBO - BCD value from table below (Input, no default)

SUB1 - BCD value from table below (Input, no default)

Note: The set equation MAJØR = SUBO + SUB1 should hold.

parameter value	USET matrix
M	U_m
S	U_s (union of SG and SB)
Ø	U_o
R	U_r
G	U_g
N	U_n
F	U_f
A	U_a
L	U_ℓ
SG	U_s (specified on Grid card)
SB	U_s (specified on SPC card)
E	U_e
P	U_p

NE	U_{ne} (union of N and E)
FE	U_{fe} (union of F and E)
D	U_d
PS	U_{ps}
SA	U_{sA}
K	U_k
PA	U_{pA}

I. NAME: UPARTN (Partitions a matrix based on USET)

II. PURPOSE: To perform symmetric partitioning of matrices (particularly to allow user splitting of long running modules such as SMP1).

III. DMAP CALLING SEQUENCE:

UPARTN USET,KII / KJJ,KLJ,KJL,KLL / V,N,MAJØR=I / V,N,SUBO=J / V,N,SUB1=L $

IV. INPUT DATA BLOCKS:

USET - displacement set definitions

KII - Any displacement matrix

Note: 1. The set definitions may be USET (statics), USETD (dynamics), HUSET (heat transfer), or USETA (aeroelastic).

2. USET may not be purged.

3. KII may be purged in which case UPARTN will simply return, causing the output matrices to be purged.

V. OUTPUT DATA BLOCKS:

$$\left.\begin{array}{l}\text{KJJ}\\ \text{KLJ}\\ \text{KJL}\\ \text{KLL}\end{array}\right\}\ \text{matrix partitions}$$

Note: 1. Any or all output data block(s) may be purged.

2. UPARTN forms:

$$\left[K_{ii}\right] \Longrightarrow \left[\begin{array}{c|c} K_{jj} & K_{j\ell} \\ \hline K_{\ell j} & K_{\ell\ell} \end{array}\right]$$

VI. PARAMETERS:

MAJØR - BCD value from table below (Input, no default)

SUBO - BCD value from table below (Input, no default)

SUB1 - BCD value from table below (Input, no default)

Note: The set equation MAJØR = SUBO + SUB1 should hold.

parameter value	USET matrix
M	U_m
S	U_s (union of SG and SB)
Ø	U_o
R	U_r
G	U_g
N	U_n
F	U_f

(Continued)

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A	U_a
L	U_ℓ
SG	U_s (specified on Grid card)
SB	U_s (specified on SPC card)
E	U_e
P	U_p
NE	U_{ne} (union of N and E)
FE	U_{fe} (union of F and E)
D	U_d
PS	U_{ps}
SA	U_{sA}
K	U_k
PA	U_{pA}

VII. EXAMPLE:

In Rigid Format 2, module SMP1 performs the following calculations:

SMP1 partitions the constrained stiffness and mass matrices

$$\left[K_{ff}\right] \Longrightarrow \left[\begin{array}{c|c} \overline{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right]$$

and

$$\left[M_{ff}\right] \Longrightarrow \left[\begin{array}{c|c} \overline{M}_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right] ,$$

solves for transformation matrix

$$[G_o] = -[K_{oo}]^{-1} [K_{oa}]$$

and performs the matrix reductions

$$[K_{aa}] = [\overline{K}_{aa}] + [K_{oa}]^T [G_o]$$

and

$$[M_{aa}] = [\overline{M}_{aa}] + [M_{oa}]^T [G_o] + [G_o]^T [M_{oa}] + [G_o]^T [M_{oo}] [G_o].$$

(Continued)

UPARTN (Cont.)

Step 1 can be performed by two applications of UPARTN:

UPARTN USET,KFF / KAAB,KØA,,KØØ / *F*/*A*/*Ø* $

UPARTN USET,MFF / MAAB,MØA,,MØØ / *F*/*A*/*Ø* $

Step 2 can be performed by SØLVE

SØLVE KØØ,KØA / GØ / 1 / -1 $

KAA and MAA can then be computed by a sequence of applications of the MPYAD module.

Thus, in the above manner, a long running module can be broken down into several smaller steps and the intermediate results can be checkpointed.

5.5 UTILITY MODULES

Utility modules are an arbitrary sub-division of the Functional Modules and are used to output matrix and table data blocks and to manipulate parameters.

The data block names corresponding to the various matrix and table data blocks used in the

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Rigid Format DMAP sequences may be found in Section 3 or in the NASTRAN mnemonic dictionary, Section 7.

I. NAME: CØPY

II. PURPOSE: To generate a physical copy of a data block.

III. DMAP CALLING SEQUENCE:

CØPY DB1 / DB2 / PARAM $

IV. INPUT DATA BLOCKS:

DB1 - Any NASTRAN data block

V. OUTPUT DATA BLOCKS:

DB2 - Any valid NASTRAN data block name

VI. PARAMETERS:

PARAM - If PARAM < 0 the copy will be performed - integer, input, default = -1.

VII. METHOD: If PARAM ≥ 0 a return is made, otherwise a physical copy of the input data block is generated.

VIII. REMARKS:

1. The input data block may not be purged.

I. NAME: INPUT (Input Generator)

II. PURPØSE: Generates the majority of the bulk data cards for selected academic problems. Used in many of the official NASTRAN Demonstration Problems.

III. DMAP CALLING SEQUENCE:

INPUT I1,I2,I3,I4,I5 / Ø1,Ø2,Ø3,Ø4,Ø5 / C,N,a / C,N,b / C,N,c $

IV. INPUT DATA BLØCKS:

Appropriate preface outputs.

V. ØUTPUT DATA BLØCKS:

Appropriate for the problem being generated.

VI. PARAMETERS:

The three parameters are used in conjunction with data read by INPUT from the input stream to define the problem being generated.

VII. METHØD:

Since INPUT is intimately related to bulk data card input, a detailed description of this module has been placed in Section 2.6.

I. NAME: INPUTT1 (Reads User Files*)
(The companion module is ØUTPUT1)

II. PURPØSE: Recovers up to five data blocks from a user file and checks the user file label where the expected format is that created by Utility Module ØUTPUT1. Also used to position the user file (including handling of multiple reel tapes) prior to reading the data blocks. Multiple calls are allowed. A message is written for each data block successfully recovered and after each tape reel switch.**

III. DMAP CALLING SEQUENCE:
INPUTT1 / DB1,DB2,DB3,DB4,DB5 / V,N,P1 / V,N,P2 / V,N,P3 $

IV. INPUT DATA BLØCKS:
Input data blocks are not used in this module call statement.

V. ØUTPUT DATA BLØCKS:
DBi - Data blocks which will be recovered from one of the NASTRAN permanent files INPT, INP1, INP2 through INP9. Any or all of the output data blocks may be purged. Only nonpurged data blocks will be taken from the file. The data blocks will be taken sequentially from the file starting from a position determined by the value of the first parameter. Note that the output data block sequence A,B,,, is equivalent to ,A,,B, or ,,,A,B.

---

* The user files reside either on physical tapes or on mass storage devices.
**Currently user tape reel switching is available only on the IBM and UNIVAC versions.

VI. PARAMETERS:

1. The meaning of the first parameter (P1) value is given in the table below. (The default value is 0.)

P1 Value	Meaning
+n	Skip forward n data blocks before reading.
0	Data blocks are read starting at the current position. The current position for the first use of a file is at the label (P3). Hence, P3 counts as one data block.
-1	Rewind before reading, position file past label (P3).
-2*	Mount new reel and position new reel past label (P3) before reading.
-3	Print data block names and then rewind before reading.
-4*	Current tape reel will have an end-of-file mark written on it, will be rewound and dismounted and then a new tape reel will be mounted with ring out and rewound before reading the data blocks. This option should be used when a call to INPUTT1 is preceded by a call to ØUTPUT1 using the same User Tape.
-5	Search user file for first version of data block (DBi) requested. If any (DBi) are not found, fatal termination occurs.
-6	Search user file for final version of data block (DBi) requested. If any (DBi) are not found, fatal termination occurs.
-7	Search user file for first version of data block (DBi) requested. If any (DBi) are not found, a warning message is written on the output file and the run continues.
-8	Search user file for final version of data block (DBi) requested. If any (DBi) are not found, a warning message is written on the output file and the run continues.

*Valid only for files that reside on physical tape. See the second footnote on the last page.

2. The second parameter (P2) for this module is the User File Code shown in the table below. (The default value is 0).

User File Code	GINØ File Name
0	INPT
1	INP1
2	INP2
3	INP3
4	INP4
5	INP5
6	INP6
7	INP7
8	INP8
9	INP9

3. The third parameter (P3) for this module is used as the User File Label for NASTRAN identification. The label (P3) is an alphanumeric variable of eight characters or less (the first character must be alphabetic). The value of P3 must match a corresponding value on the user file. The comparison of P3 and the value on the user file is dependent on the value of P1 as shown in the table below. (The default value for P3 is XXXXXXXX).

P1 Value	File Label Checked
+n	No
0	No
-1	Yes
-2	Yes (On new reel)
-3	Yes (Warning Check)
-4	Yes (On new reel)
-5	Yes
-6	Yes
-7	Yes
-8	Yes

VII. EXAMPLES: (Most examples use the default value for P2 and P3 which means the use of permanent NASTRAN file INPT and NASTRAN user file label of XXXXXXXX)

1. INPUTT1 / A,B,,, / $

   Read data blocks A and then B from user file INPT starting from wherever INPT is currently positioned. If this is the first module to manipulate INPT, the file will automatically be initially positioned at the beginning of the user file label. In this case,the first parameter of INPUTT1 must be set to either one (1) to skip past the label or minus one (-1) to rewind the file and position it at the beginning of the first data block (A).

2. INPUTT1 / ,,,, / C,N,-1 / C,N,3 $

   Rewind INP3 and check user tape label.

3. INPUTT1 / A,,,, / C,N,-2 $

   Mount a new reel of file (without write ring) for INPT and read data block A from the first file position. The label of the new reel of tape will be checked.

4. INPUTT1 / ,,,, / C,N,-2 $
   INPUTT1 / A,,,, / C,N,0 $

   This is equivalent to example 3.

5. INPUTT1 / A,B,C,D,E / C,N,14 $

   Starting from the current position, skip forward 14 data blocks on INPT and read the next five data blocks into A,B,C,D, and E. Do not check the user file label.

6. INPUTT1 / ,,,, / C,N,-3 $
   INPUTT1 / A,B,C,D,E / C,N,14 $

   A complete list of data block names will be provided including a warning check of the user file label. Then, it will be the same as example 5 only if the current position in that example were at the beginning of the first data block.

7. INPUTT1 / ,,,, / C,N,-2 $
   INPUTT1 / ,,,, / C,N,-3 $
   INPUTT1 / A,B,,, / C,N,14 $

   Mount a new reel of tape for INPT and check the new reel's label. Print the names of all data blocks on the new tape and give a warning check for tape label. Read the 15th and 16th data blocks into A and B. INPT will end up positioned at the beginning of the 17th data block if present.

VIII. MORE DIFFICULT EXAMPLES USING BOTH INPUTT1 and OUTPUT1:

Example 1:

(a) Objectives:

(1) Obtain printout of the names of all data blocks on INPT.

(2) Skip past the first four data blocks, replace the next two with data blocks A and B, and retain the next three data blocks.

(3) Obtain printout of the names of all data blocks on INPT after (2) has been done.

(b) DMAP Sequence:

```
BEGIN $                                   (1)
INPUTT1  / ,,,, / C,N,-3 $                (2)
INPUTT1  / ,,T1,T2,T3 / C,N,6 $           (3)
INPUTT1  / ,,,, / C,N,-1 $                (4)
ØUTPUT1  A,B,T1,T2,T3 // C,N,4 $          (5)
ØUTPUT1, ,,,, // C,N,-3 $                 (6)
END $                                     (7)
```

(c) Remarks:

(1) DMAP sequence (2) accomplishes objective (1) and rewinds INPT.

(2) DMAP sequence (3) recovers data blocks 7, 8, and 9. This is necessary because they would be effectively destroyed by anything written in front of them on INPT.

(3) DMAP sequence (4) rewinds INPT.

(4) DMAP sequence (5) accomplishes objective (2).

(5) DMAP sequence (6) accomplishes objective (3) and leaves INPT positioned after the ninth file, ready to receive additional data blocks.

(6) Note that INPUTT1 is used whenever possible to avoid the possibility of mistakenly writing on INPT prematurely.

Example 2:

(a) Objectives:

(1) Write data blocks A, B, and C on INPT.

(2) Obtain printout of the names of all data blocks on INPT after step (1).

(3) Make two copies of the file created in (1).

(4) Add data blocks D and E to one of the files.

(5) Obtain the names of all data blocks on INPT after (4).

(b) DMAP Sequence:

```
BEGIN $                              (1)
ØUTPUT1 A,B,C,, // C,N,-1 $          (2)
ØUTPUT1, ,,,, // C,N,-3 $            (3)
ØUTPUT1 A,B,C,, // C,N,-2 $          (4)
ØUTPUT1 A,B,C,, // C,N,-2 $          (5)
ØUTPUT1 D,E,,, // C,N,0 $            (6)
ØUTPUT1, ,,,, // C,N,-3 $            (7)
END $                                (8)
```

(c) Remarks:

(1) DMAP Sequence (2) accomplishes objective (1).

(2) DMAP sequence (3) accomplishes objective (2). The statement INPUTT1 / ,,,, / C,N,-3 $ will do the same thing and add a rewind.

(3) Statements (4) and (5) accomplish objective (3).

(4) Statement (6) accomplishes objective (4) where the third file (tape) is used.

(5) Statement (7) accomplishes objective (5). The statement INPUTT1 / ,,,, / C,N,-3 $ will do the same thing and add a rewind.

(6) On machines where tape reel switching is not implemented, the second parameter can be used as follows:

```
BEGIN $
ØUTPUT1  A,B,C,, // C,N,-1 $
ØUTPUT1, ,,,, // C,N,-3 $
ØUTPUT1  A,B,C,, // C,N,-1 / C,N,1 $
ØUTPUT1  A,B,C,, // C,N,-1 / C,N,2 $
ØUTPUT1  D,E,,, // C,N,0 / C,N,2 $
ØUTPUT1, ,,,, // C,N,-3 / C,N,2 $
END $
```

I. NAME: INPUTT2 (Reads User-Written FØRTRAN Files*)
(The companion module is ØUTPUT2)

II. PURPØSE: Recovers up to five data blocks from a FØRTRAN-written user file. This file may be written either by a user-written FØRTRAN program or by the companion module ØUTPUT2. The Programmer's Manual describes the format of the file which must be written in order to be readable by INPUTT2.

III. DMAP CALLING SEQUENCE:
INPUTT2 / DB1,DB2,DB3,DB4,DB5 / V,N,P1 / V,N,P2 / V,N,P3 $

IV. INPUT DATA BLØCKS:
Input data blocks are not used in this module call statement.

V. ØUTPUT DATA BLØCKS:
DBi - Data blocks which will be recovered from one of the NASTRAN FØRTRAN tape files UT1, UT2, through UT5. Any or all of the output data blocks may be purged. Only non-purged data blocks will be taken from the file. The data blocks will be taken sequentially from the file starting from a position determined by the value of the first parameter. Note that the output data block sequence A,B,,, is equivalent to ,A,,B, or ,,,A,B .

*The FØRTRAN files may reside either on physical tapes or on mass storage devices.

VI. PARAMETERS:

1. The meaning of the first parameter (P1) value is given in the table below. (The default value is 0.)

P1 Value	Meaning
+n	Skip forward n data blocks before reading.
0	Data blocks are read starting at the current position. The current position for the first use of a file is at the label (P3). Hence, P3 counts as one data block.
-1	Rewind before reading, position file past label (P3).
-3	Print data block names and then rewind before reading.
-5	Search user file for first version of data block (DBi) requested. If any (DBi) are not found, fatal termination occurs.
-6	Search user file for final version of data block (DBi) requested. If any (DBi) are not found, fatal termination occurs.
-7	Search user file for first version of data block (DBi) requested. If any (DBi) are not found, a warning message is written on the output file and the run continues.
-8	Search user file for final version of data block (DBi) requested. If any (DBi) are not found, a warning message is written on the output file and the run continues.

Important Note

On the UNIVAC and DEC VAX versions, the FØRTRAN files used with the INPUTT2/ØUTPUT2 modules are automatically rewound every time a link change occurs in the program. In general, a link change can be assumed to occur whenever a DMAP statement other than an INPUTT2 statement follows an INPUTT2 statement; similarly, whenever a DMAP statement other than an ØUTPUT2 statement follows an ØUTPUT2 statement. For this reason, the following cautions should be noted on these versions when using the various values for the parameter P1 in an INPUTT2 or ØUTPUT2 DMAP statement.

Cautions for UNIVAC and DEC VAX versions

Parameter P1	Remarks
0 or +n	The user must be certain that this INPUTT2 statement immediately follows another INPUTT2 statement; or that this ØUTPUT2 statement immediately follows another ØUTPUT2 statement, to avoid a link change that would cause the rewinding of the FØRTRAN file.
-1 to -8	No cautions
-9	The user must be certain that this ØUTPUT2 statement immediately follows another ØUTPUT2 statement, to avoid a link change that would cause the rewinding of the FØRTRAN file.

2. The second parameter (P2) for this module is the FØRTRAN unit number from which the data blocks will be read. The allowable values for this parameter are highly machine- and installation-dependent. Reference should be made to Section 4 of the Programmer's Manual for a discussion of this problem. (The default value for P2 is 11.)

User File Code	FØRTRAN File Name
11	UT1
12	UT2
13	UT3
14	UT4
15	UT5

The third parameter (P3) for this module is used as the FØRTRAN User File Label for NASTRAN identification. The label (P3) is an alphanumeric variable of eight characters or less (the first character must be alphabetic). The value of P3 must match a corresponding value on the FØRTRAN user file. The comparison of P3 and the value on the user file is dependent on the value of P1 as shown in the table below. (The default value for P3 is XXXXXXXX.)

P1 Value	File Label Checked
+n	No
0	No
-1	Yes
-3	Yes (Warning Check)
-5	Yes
-6	Yes
-7	Yes
-8	Yes

VII. EXAMPLES:

INPUTT2 is intended to have the same logical action as the GINØ User File module INPUTT1 except for tape reel switching. It is therefore suggested that the examples shown under module INPUTT1 be used for INPUTT2 as well, excepting the ones involving tape reel switching.

I. NAME: LAMX (LAMA Data Block Editor or Generator)

II. PURPOSE: Allows modification of mode frequencies, which is useful in dynamics rigid formats. This can be used, for example, to test the effects of structural uncertainties. It does not require a new eigensolution.

III. DMAP CALLING SEQUENCE:

LAMX EDIT,LAMA/LAMB/C,Y,NLAM $

IV. INPUT DATA BLOCKS:

EDIT - The editing instruction in the form of a DMI matrix.

LAMA - An output of the READ module which contains frequencies and generalized masses. If purged, the output is generated solely from EDIT information.

V. OUTPUT DATA BLOCKS:

LAMB - An edited version of LAMA, which is suitable for input to GKAM and ØFP modules, or a matrix from LAMA.

VI. PARAMETER:

NLAM - Integer. The maximum number of modes in the output data block. If NLAM = 0, the number of modes in LAMB is equal to that of LAMA. If NLAM < 0, LAMB will be a matrix.

VII. METHOD:

The DMI matrix (named EDIT in the above calling sequence) has one column for each mode. Each column has, at most, three entries (rows). Let R_{1n}, R_{2n}, and R_{3n} be the entries in the first through third rows of the nth column. The nth column will edit the frequency f_n and the generalized mass m_n of the nth mode. The rules defined below are such that a null column produces no change, while both a fixed frequency shift or a percentage change may be specified.

1. If $R_{3n} < 0$, delete the mode and decrease the mode number of higher modes.
2. If $R_{3n} \geq 0$,

$$\text{Frequency} = R_{1n} + (1+R_{2n})f_n$$

$$\text{Generalized mass} = \begin{cases} m_n , & R_{3n} = 0 \\ R_{3n} , & R_{3n} > 0 \end{cases}$$

The change for generalized mass is ignored unless data block MI is purged. The module will generate a LAMB data block if the second input is purged.

$$\text{Frequency} = R_{1n}$$
$$\text{Generalized mass} = R_{3n}$$

This second option is useful if modes are created external to NASTRAN and are input into the program via USER modules or DMI Bulk Data cards.

If NLAM is less than zero, a matrix will be built on LAMB. EDIT is ignored, and columns will be built with eigenvalue, omega, frequency, generalized mass, and generalized stiffness until the generalized mass is zero. The number of rows should then match the number of eigenvectors requested.

VIII. REMARKS:

1. LAMA may be purged. If LAMA is purged, than a LAMB is created from the EDIT information.

IX. EXAMPLES:

1. Assume that ten modes were found by READ and it is desired to do the following:

1 - 3	Leave alone
4	Multiply frequency by .8
5	Leave alone
6	Delete
7	Replace frequency by 173.20
8	Delete

The ALTER would be:

```
ALTER  XX
LAMX   LLLL,LAMA/LAMB/C,N,7 $
EQUIV  LAMB, LAMA/ALWAYS
```

This ALTER must be placed after READ and before GKAM. The DMI Bulk Data card would be:

1	2	3	4	5	6	7	8	9	10
DMI	LLLL	0	2	1	1		3	7	
DMI	LLLL	4	1	0.	-.2				
DMI	LLLL	6	1	0.	0.	-1.			
DMI	LLLL	7	1	173.20	-1.				

2. Create a LAMA with f_i = 10., 20., 30., 40., and m_i = 1., 1., 1., 2.

```
ALTER  XX
LAMX   EDIT,/LAMA $ DEFAULT PARAMETER IS ZERØ.
ØFP    LAMA,,,,,// $
```

1	2	3	4	5	6	7	8	9	10
DMI	EDIT	0	2	1	1		3	4	
DMI	EDIT	1	1	10.	0.	1.			
DMI	EDIT	2	1	20.	0.	1.			
DMI	EDIT	3	1	30.	0.	1.			
DMI	EDIT	4	1	40.	0.	2.			

I. NAME: MATGPR (Displacement Set Matrix Printer)

II. PURPØSE: Prints matrices associated with set definitions. External grid point identification of each nonzero element is also printed.

III. DMAP CALLING SEQUENCE:

A. For matrices generated in Rigid Formats 1-6 or matrices generated in Rigid Formats 7-12 prior to module GKAD (or GKAM):

MATGPR GPL,USET,SIL,M // C,N,c / C,N,r $

B. For matrices generated in Rigid Formats 7-12 after module GKAD (or GKAM);

MATGPR GPLD,USETD,SILD,M // C,N,c / C,N,r $

IV. INPUT DATA BLØCKS:

GPL - Grid Point List
GPLD - Grid Point List (Dynamics)
USET - Displacement Set Definition (Statics)
USETD - Displacement Set Definition (Dynamics)
HUSET - Displacement Set Definition (Heat Transfer)
USETA - Displacement Set Definition (Aeroelastic)
SIL - Scalar Index List
SILD - Scalar Index List (Dynamics)
M - Any displacement set matrix

V. ØUTPUT DATA BLØCKS: None

VI. PARAMETERS:

1. c-row size (number of columns) - must be the appropriate BCD value from the table below. (Input, no default)

2. r-column size (number of rows) - must be the appropriate BCD value from the table below. If not specified, it will be assumed that r=c. (Input, default = X which implies r=c)

MATGPR parameter value	Means matrix is same size as
M	U_m
S	U_s (union of SG and SB)
Ø	U_o
R	U_r
G	U_g
N	U_n
F	U_f
A	U_a
L	U_ℓ
SG	U_s (specified on GRID card)

SB	U_s (specified on SPC card)
E	U_e
P	U_p
NE	U_{ne} (union of N and E)
FE	U_{fe} (union of F and E)
D	U_d
PS	U_{ps}
SA	U_{sA}
K	U_k
PA	U_{pA}

Notes:

1. See Section 1.4 for a discussion of set notation.
2. If the value specified for c is not in the above table, the matrix will not be printed.
3. The user must know which sets correspond to the rows and columns of the matrix he wishes to print. This is usually apparent from the DMAP name of the matrix data block.

VII. REMARKS:

1. When using the form specified in IIIA, this module may not be scheduled until after GP4 since data blocks generated by GP4 are required inputs. When using the form specified in IIIB, this module may not be scheduled until after DPD since data blocks generated by DPD are required inputs.
2. If [M] is purged, no printing will be done.
3. The non-zero terms of the matrix will be printed along with the external grid point and component identification numbers corresponding to the row and column position of each term.

I. NAME: MATPRN (General Matrix Printer)

II. PURPØSE: To print general matrix data blocks.

III. DMAP CALLING SEQUENCE:

```
MATPRN  M1,M2,M3,M4,M5 // $
```

IV. INPUT DATA BLØCKS:

Mi - Matrix data blocks, any of which may be purged.

V. ØUTPUT DATA BLØCKS: None

VI. PARAMETERS: None

VII. ØUTPUT:

The nonzero band of each column of each input matrix data block is unpacked and printed in single precision.

VIII. NØTES:

1. Any or all input data blocks can be purged.
2. If any data block is not matrix type, the TABPT routine will be called.

IX. EXAMPLES:

```
1. MATPRN  KGG,,,, // $
2. MATPRN  KGG,PL,PG,BGG,UPV // $
```

DIRECT MATRIX ABSTRACTION

I. NAME: MATPRT (Matrix Printer)

II. PURPOSE: To print matrix data blocks associated with grid points only.

III. DMAP CALLING SEQUENCE:

```
MATPRT  X // C,N,rc / C,N,y $
```

IV. INPUT DATA BLOCK:

X - matrix data block to be printed. If [X] is purged, then nothing is done.

V. OUTPUT DATA BLOCKS: None

VI. PARAMETERS:

1. rc - indicates whether [X] is stored by rows (rc = 1) or by columns (rc = 0) (integer, input, default value = 0).

2. y - indicates whether [X] is to be printed even if not purged ($y < 0$, do not print [X]; $y \geq 0$, print [X]) (integer, input, default value = 0).

VII. METHOD:

Each column (or row) of the matrix is broken into groups of 6 terms (3 terms if complex) per printed line. If all the terms in a group = 0, the line is not printed. If the entire column (or row) = 0, it is not printed. If the entire matrix = 0, it is not printed.

VIII. REMARKS:

1. MATPRT should not be used if scalar or extra points are present. For this case, use MATPRN.

2. Only one matrix data block is printed by this instruction. The instruction may be repeated as many times as required, however.

I. NAME: ØUTPUT1 (Create User Files*)
(The companion module is INPUTT1)

II. PURPØSE: Writes up to five data blocks and a user file label onto a user file for subsequent use at a later date. (See User Module INPUTT1 for recovery procedures.) ØUTPUT1 is also used to position the user file (including handling of multiple reel tapes**) prior to writing the data blocks. Multiple calls are allowed. A message is written on the output file for each data block successfully written and after each tape reel switch. The user is cautioned to be careful when positioning a user file with ØUTPUT1 since he may inadvertently destroy information through improper positioning. Even though no data blocks are written, an EØF will be written at the completion of each call which has the effect of destroying anything on the file forward of the current position.

III. DMAP CALLING SEQUENCE:

```
ØUTPUT1  DB1,DB2,DB3,DB4,DB5  // V,N,P1 / V,N,P2 / V,N,P3 $
```

IV. INPUT DATA BLØCKS:

DBi - Any data block which the user desires to be placed on one of the NASTRAN permanent files INPT, INP1, INP2 thru INP9. Any or all of the input data blocks may be purged. Only nonpurged data blocks will be placed on the file.

V. ØUTPUT DATA BLØCKS: None.

*The user files may reside either on physical tapes or on mass storage devices.
**User tape reel switching is currently available only on the IBM and UNIVAC versions.

VI. PARAMETERS:

1. The meaning of the first parameter (P1) value is given in the table below. (The default value is 0.)

P1 Value	Meaning
+n	Skip forward n data blocks before reading.
0	Data blocks are written starting at the current position. The current position for the first use of a file is at the label (P3). In this case, P3 counts as one data block.
-1	Rewind before writing. (This is dangerous!)*
-2**	Mount new reel before writing.***
-3	Rewind files, print data block names and then write after the last data block on the file.
-4**	Current tape reel will be rewound and dismounted and a new tape reel will be mounted with ring in and rewound before writing the data blocks. This option should be used when a call to ØUTPUT1 is preceded by a call to INPUTT1 using the same User Tape.

2. The second parameter (P2) for this module is the User File Code shown in the table below. (The default value is 0.)

User File Code	GINØ File Name
0	INPT
1	INP1
2	INP2
3	INP3
4	INP4
5	INP5
6	INP6
7	INP7
8	INP8
9	INP9

* An EØF is written at the end of each call to ØUTPUT1.
** Valid only for files that reside on physical tape. See the second foot note on the last page.
***An end-of-file mark is written on the tape to be switched. Caution should be used when switching from a user tape being read by INPUTT1 to a tape to be written by ØUTPUT1.

3. The third parameter (P3) for this module is used to define the User File Label. The label is used for NASTRAN identification. The label (P3) is an alphanumeric variable of eight or less characters (the first character must be alphabetic) which is written on the user file. The writing of this label is dependent on the value of P1 as follows: (The default value for P3 is XXXXXXXX).

P1 Value	File Label Written
+n	No
0	No
-1	Yes
-2	Yes (On New Reel)
-3	No (Warning Check)
-4	Yes (On New Reel)

The user may specify the third parameter as V, Y, name. The user then must also include a PARAM card in the bulk data deck to set a value for name.

VII. EXAMPLES:

1. ØUTPUT1 A,B,,, // C,N,0 / C,N,0 $ or ØUTPUT1 A,B,,, // $
Write data blocks A and then B onto user file INPT starting wherever INPT is currently positioned. If this is the first write operation on INPT, it must be preceded by ØUTPUT1 ,,,, // C,N,-1 $ which will automatically label the file positioned at its beginning.

2. ØUTPUT1, ,,,, // C,N,-1 / C,N,0 $
Rewind INPT and destroy any data blocks that were on INPT and write default value of P3 on file as a label.

3. ØUTPUT1 A,,,, // C,N,-2 / C,N,2 / C,N,USERTPA $
Mount a new reel of tape (with write ring) for INP2 and write USERTPA for user tape label and then data block A as the first file.

4. ØUTPUT1, ,,,, // C,N,-2 / C,N,2 / C,N,USERTPA $
ØUTPUT1 A,,,, // C,N,0 / C,N,2 $
This is equivalent to example 3.

5. ØUTPUT1 A,B,C,D,E // C,N,14 $
Starting from the current position, skip forward 14 data blocks on INPT and write A,B,C,D, and E as the next five data blocks. The skip positioning feature cannot be used if the current position of INPT is forward of a just previously written data block end-of-file or before the file is labeled.

6. ØUTPUT1, ,,,, // C,N,-3 $ THIS IS AN
ØUTPUT1 A,B,C,D,E // C,N,14 $ IMPRØPER EXAMPLE.
This is an invalid sequence since the first call positions the tape at the end of all data blocks on the tape. See example 7.

7. INPUTT1 / ,,,, / C,N,-3 $
ØUTPUT1 A,B,C,D,E // C,N,14 $
A complete list of data block names will be printed by INPUTT1 which will then rewind the file. Then, ØUTPUT1 will skip forward 14 data blocks and write A,B,C,D, and E. The user file label is given a warning check by INPUTT1.

8. ØUTPUT1, ,,,, // C,N,-2 $ THIS IS AN
ØUTPUT1, ,,,, // C,N,-3 $ IMPRØPER EXAMPLE.
ØUTPUT1, A,B,,, // C,N,14 $
This is an invalid sequence since the first call effectively destroys whatever information is on the tape. See example 9.

9.
```
INPUTT1 / ,,,, / C,N,-2 $
INPUTT1 / ,,,, / C,N,-3 $
ØUTPUT1 A,B,,, // C,N,14 $
```
Mount a new reel of tape previously default labeled for INPT (the operator will have to be instructed to ignore the NØRING message and put a ring in the tape). Print the names of all data blocks on the tape and rewind the tape. Skip 14 data blocks on the tape and write A and then B as the 15th and 16th data blocks. Any information forward of this current position is effectively destroyed. See example 10.

10.
```
INPUTT1 / ,,,, / C,N,-2 $
ØUTPUT1 A,B,,, // C,N,-3 $
```
Mount a new reel of tape previously default labeled for INPT (the operator will have to be instructed to ignore the NØRING message and put a ring in the tape). Print the names of all data blocks on the tape and write A and B as new data blocks at the end of the tape. If INPT contained 14 data blocks at the start of this sequence, it would be more efficient to do it this way than by using the sequence of example 9 since a pass on the tape is eliminated.

11.
```
INPUTT1 / ,,,, / C,N,-2 / C,N,0 / V,Y,BDSETLAB $
ØUTPUT1 A,B,,, // C,N,-3 / C,N,0 / V,Y,BDSETLAB $
```
This is equivalent to example 10 except the user tape label is set on a PARAM card which must be included in the BULK DATA deck (i.e., PARAM BDSETLAB USERTP12).

VIII. DIFFICULT EXAMPLES USING INPUTT1 and OUTPUT1:

Example 1:

(a) Objectives:

(1) Obtain printout of the names of all data blocks on INPT.

(2) Skip past the first four data blocks, replace the next two with data blocks A and B, and retain the next three data blocks.

(3) Obtain printout of the names of all data blocks on INPT after (2) has been done.

(b) DMAP Sequence:

```
BEGIN $                                  (1)
INPUTT1 / ,,,, / C,N,-3 $                (2)
INPUTT1 / ,,T1,T2,T3 / C,N,6 $           (3)
INPUTT1 / ,,,, / C,N,-1 $                (4)
ØUTPUT1 A,B,T1,T2,T3 // C,N,4 $          (5)
ØUTPUT1, ,,,, // C,N,-3 $                (6)
END $
```

(c) Remarks:

(1) DMAP sequence (2) accomplishes objective (1) and rewinds INPT.

(2) DMAP sequence (3) recovers data blocks 7,8, and 9. This is necessary because they would be effectively destroyed by anything written in front of them on INPT.

(3) DMAP sequence (4) rewinds INPT.

(4) DMAP sequence (5) accomplishes objective (2).

(5) DMAP sequence (6) accomplishes objective (3) and leaves INPT positioned after the ninth file, ready to receive additional data blocks.

(6) Note that INPUTT1 is used whenever possible to avoid the possibility of mistakenly writing on INPT prematurely.

Example 2:

(a) Objectives:

(1) Write data blocks A, B, and C on INPT.

(2) Obtain printout of the names of all data blocks on INPT after step (1).

(3) Make two copies of the file created in (1).

(4) Add data blocks D and E to one of the files.

(5) Obtain the names of all data blocks on INPT after (4).

(b) DMAP Sequence:

```
BEGIN $                                  (1)
ØUTPUT1 A,B,C,, // C,N,-1 $              (2)
ØUTPUT1, ,,,, // C,N,-3 $                (3)
ØUTPUT1 A,B,C,, // C,N,-2 $              (4)
ØUTPUT1 A,B,C,, // C,N,-2 $              (5)
ØUTPUT1 D,E,,, // $                      (6)
ØUTPUT1, ,,,, // C,N,-3 $                (7)
END $                                    (8)
```

(c) Remarks:

(1) DMAP sequence (2) accomplishes objective (1) since the file must initially have P3 written on it when first used. The DMAP statement INPUTT1 A,B,C,, // C,N,-1 $ will accomplish the same thing.

(2) DMAP sequence (3) accomplishes objective (2). The statement INPUTT1 / ,,,, / C,N,-3 $ will do the same thing and add a rewind.

(3) Statements (4) and (5) accomplish objective (3).

(4) Statement (6) accomplishes objective (4) where the third file (tape) is used.

(5) Statement (7) accomplishes objective (5). The statement INPUTT1 / ,,,, / C,N,-3 $ will do the same thing and add a rewind.

(6) On machines where tape reel switching is not implemented, the second parameter can be used as follows:

```
BEGIN $
ØUTPUT1 A,B,C,, // C,N,-1 $
ØUTPUT1, ,,,, // C,N,-3 $
ØUTPUT1 A,B,C,, // C,N,-1 / C,N,1 $
ØUTPUT1 A,B,C,, // C,N,-1 / C,N,2 $
ØUTPUT1 D,E,,, // C,N,0 / C,N,2 $
ØUTPUT1, ,,,, // C,N,-3 / C,N,2 $
END $
```

I. NAME: ØUTPUT2 (Create User Written FØRTRAN Files*)
(The companion module is INPUTT2)

II. PURPØSE: Writes up to five data blocks and a user file label onto a FØRTRAN-written user file for subsequent use at a later date. ØUTPUT2 is also used to position the user file prior to writing the data blocks. Multiple calls are allowed. A message is written on the output file for each data block successfully written. The user is cautioned to be careful when positioning a user file with ØUTPUT2 since he may inadvertently destroy information through improper positioning. Even though no data blocks are written, an EØF will be written at the completion of each call which has the effect of destroying anything on the tape forward of the current position.

III. DMAP CALLING SEQUENCE:

ØUTPUT2 DB1,DB2,DB3,DB4,DB5 // V,N,P1 / V,N,P2 / V,N,P3 $

IV. INPUT DATA BLØCKS:

DBi - Any data block which the user desires to be written on one of the NASTRAN FØRTRAN files UT1, UT2 through UT5. Any or all of the input data blocks may be purged. Only nonpurged data blocks will be placed on the file.

V. ØUTPUT DATA BLØCKS: None.

VI. PARAMETERS:

1. The meaning of the first parameter (P1) value is given in the table below. (The default value is 0.)

P1 Value	Meaning
+n	Skip forward n data blocks before wtiting.
0	Data blocks are written starting at the current position. The current position for the first use of a file is at the label (P3). In this case, P3 counts as one data block.
-1	Rewind before writing.
-3	Rewind files, print data block names and then write after the last data block on the file.
-9	Write a final EØF on the file.

*The FØRTRAN files may reside either on physical tapes or on mass storage devices.

Important Notes:

1. It is a good practice for the user to ensure that a sequence of ØUTPUT2 statements always ends with a statement of the form

   ØUTPUT2 ,,,, // -9 $

   thereby causing a final (or physical) EØF to be written on the FØRTRAN file. Otherwise, subsequent use of this file with an ØUTPUT2 or INPUTT2 statement may fail due to the absence of a physical EØF on the file.

2. On the UNIVAC and DEC VAX versions, the FØRTRAN files used with the INPUTT2/ØUTPUT2 modules are automatically rewound every time a link change occurs in the program. In general, a link change can be assumed to occur whenever a DMAP statement other than an INPUTT2 statement follows an INPUTT2 statement; similarly, whenever a DMAP statement other than an ØUTPUT2 statement follows an ØUTPUT2 statement. For this reason, the following cautions should be noted on these versions when using the various values for the parameter P1 in an INPUTT2 or ØUTPUT2 DMAP statement.

Cautions for UNIVAC and DEC VAX versions

Parameter P1	Remarks
0 or +n	The user must be certain that this INPUTT2 statement immediately follows another INPUTT2 statement; or that this ØUTPUT2 statement immediately follows another ØUTPUT2 statement, to avoid a link change that would cause the rewinding of the FØRTRAN file.
-1 to -8	No cautions
-9	The user must be certain that this ØUTPUT2 statement immediately follows another ØUTPUT2 statement, to avoid a link change that would cause the rewinding of the FØRTRAN file.

2. The second parameter (P2) for this module is the FØRTRAN unit number onto which the data blocks will be written. The allowable values for this parameter are highly machine- and installation-dependent. Reference should be made to Section 4 of the Programmer's Manual for a discussion of this problem. (The default value for P2 is 11.)

User File Code	FØRTRAN File Name
11	UT1
12	UT2
13	UT3
14	UT4
15	UT5

3. The third parameter (P3) for this module is used to define the FØRTRAN User File Label. The label is used for NASTRAN identification. The label (P3) is an alphanumeric variable of eight or less characters (the first character must be alphabetic) which is written on the user file. The writing of this label is dependent on the value of P1 as follows: (The default value for P3 is XXXXXXXX.)

P1 Value	File Label Written
+n	No
0	No
-1	Yes
-3	No (Warning Check)
-9	No

The user may specify the third parameter as V,Y,name. The user then must also include a PARAM card in the bulk data deck to set a value for name.

VII. EXAMPLES:

ØUTPUT2 is intended to have the same logical action as the GINØ User File module ØUTPUT1 except for tape reel switching. It is therefore suggested that the examples shown under module ØUTPUT1 be used for ØUTPUT2 as well, excepting the ones involving tape reel switching. All examples should be ended with a call to ØUTPUT2 with P1 = -9.

VIII. REMARKS:

The primary objective of this module is to write files using simple FØRTRAN so that a user can read NASTRAN generated data with his own program. Similarly, matrices can be generated with externally written simple FØRTRAN programs and then read in by module INPUTT2.

In order to do this, the format of the information on these files must be adhered to. The basic idea is that a one word logical KEY record is written which indicates what follows. A zero value indicates an end-of-file condition. A negative value indicates the end of a record where the absolute value is the record number. A positive value indicates that the next record consists of that many words of data.

DIRECT MATRIX ABSTRACTION

The correspondence between FØRTRAN records and GINØ-written NASTRAN files is shown in the following sample:

FØRTRAN Record	Length	Contents	NASTRAN File	File Record
1	1	KEY > 0	1	1
2	KEY	{Data} KEY		
3	1	KEY > 0		
4	KEY	{Data} KEY		
5	1	KEY < 0 (EØR)		
6	1	KEY > 0		2
7	KEY	{Data} KEY		
8	1	KEY < 0 (EØR)		
9	1	KEY = 0 (EØF)		EØF
10	1	KEY > 0	2	1
11	KEY	{Data} KEY		
12	1	KEY < 0 (EØR)		
13	1	KEY = 0 (EØF)		EØF
14	1	KEY = 0 (EØF=EØD)	3	EØF

I. NAME: ØUTPUT3 (Punch Matrix Data Blocks onto Cards)

II. PURPØSE: Punches up to five matrix data blocks onto DMI bulk data cards. These cards may then read into NASTRAN as ordinary bulk data to reestablish the matrix data block at a later date.

III. DMAP CALLING SEQUENCE:

```
ØUTPUT3  M1,M2,M3,M4,M5 // C,N,P1 / C,Y,N1=ABC / C,Y,N2=DEF / C,Y,N3=GHI /
                                    C,Y,N4=JKL / C,Y,N5=MNØ $
```

IV. INPUT DATA BLØCKS:

Mi - Any matrix data block which the user desires to be punched on DMI cards. Any or all of the input data blocks may be purged. Only nonpurged data blocks will be punched.

V. ØUTPUT DATA BLØCKS: None

VI. PARAMETERS:

The first parameter (P1) controls the writing of the DMI card images on a FØRTRAN unit as follows:

$P1 < 0$ write on FØRTRAN unit $|P1|$ as well as punch DMI cards

$P1 \geq 0$ punch DMI cards only

The default value for P1 is 0.

Ni - The values of the five BCD parameters shown above are used to create a unique continuation field configuration on the DMI cards. Only the first three characters are used. These three characters must be unique for all matrices which will be input together during a subsequent run using cards generated by ØUTPUT3. (Input, BCD, default values are N1 = no default, N2=N3=N4=N5=XXX).

VII. METHØD: The nonzero elements of each matrix are punched on double-field DMI cards as shown in the example below. The name of the matrix is obtained from the header record of the data block. Field 10 contains the three character parameter value in columns 74-76 and an incremented integer card count in columns 77-80.

VIII. EXAMPLE:

Let the data block MAT contain the matrix

$$[MAT] = \begin{bmatrix} 1.0 & 0.0 & 6.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 7.0 & 0.0 & 0.0 & 0.0 \\ 2.0 & 4.0 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 5.0 & 0.0 & 0.0 & 0.0 & 9.0 \\ 3.0 & 0.0 & 8.0 & 0.0 & 0.0 & 0.0 \end{bmatrix}$$

The DMAP instruction OUTPUT3 MAT,,,, // C,N,0 / C,N,XYZ $ will then punch out the DMI cards shown below.

DMI	MAT	0	2	1	2		5	6	+XYZ 0

DMI*	MAT	1	1	1.000000E 00	*XYZ 1
*XYZ 1	3	2.000000E 00	5	3.000000E 00	*XYZ 2
DMI*	MAT	2	3	4.000000E 00	*XYZ 3
*XYZ 3	5.000000E 00				*XYZ 4
DMI*	MAT	3	1	6.000000E 00	*XYZ 5
*XYZ 5	7.000000E 00	5	8.000000E 00		*XYZ 6
DMI*	MAT	6	4	9.000000E 00	*XYZ 7

IX. REMARKS:

1. Only real single- or double-precision matrices may be output.
2. All matrices are output on double-field cards in single-precision.
3. The maximum number of cards that may be punched is 99,999. If matrices larger than this are desired, use module ØUTPUT2 and write a program to process the resulting FØRTRAN file.
4. The auxiliary subroutine PHDMIA used by module ØUTPUT3 can be used with stand-alone FØRTRAN programs. See Section 4 of the Programmer's Manual for details.

I. NAME: PARAM (Parameter Processor)

II. PURPOSE: To perform specified operations on integer DMAP parameters.

III. DMAP CALLING SEQUENCE:

PARAM // C,N,op / V,N,ØUT / V,N,IN1 / V,N,IN2 $

IV. INPUT DATA BLOCKS: None

V. OUTPUT DATA BLOCKS: None

VI. PARAMETERS:

1. op is a BCD operation code from the table below (Input, no default). Op is usually specified as a "C,N" parameter.
2. ØUT is the name of the parameter which is being generated by PARAM (output, integer, default = 1).
3. IN1 is the name of a parameter whose value is used to compute ØUT according to the table below (Input, integer, default = 1).
4. IN2 is the name of a parameter whose value is used to compute ØUT according to the table below (Input, integer, default = 1).

VII. REMARKS:

1. The tables below give the results for ØUT as a function of op, IN1, and IN2.

Param	Arithmetic Operations				
op	ADD	SUB	MPY	DIV	NØT
ØUT	IN1+IN2	IN1-IN2	IN1·IN2	IN1/IN2	-IN1

Param	Logical Operations											
op	AND				ØR				IMPL			
IN1	<0	<0	≥0	≥0	<0	<0	≥0	≥0	<0	<0	≥0	≥0
IN2	<0	≥0	<0	≥0	<0	≥0	<0	≥0	<0	≥0	<0	≥0
ØUT	-1	+1	+1	+1	-1	-1	-1	+1	-1	+1	-1	-1

Param	Arithmetic Relational Operations																	
op	EQ			GE			GT			LE			LT			NE		
IN1-IN2	<0	=0	>0	<0	=0	>0	<0	=0	>0	<0	=0	>0	<0	=0	>0	<0	=0	>0
ØUT	+1	-1	+1	+1	-1	-1	+1	+1	-1	-1	-1	+1	-1	+1	+1	-1	+1	-1

Param	Special Operations
op	ØUT
NØP	ØUT (unchanged)
KLØCK	Current CPU time in integer seconds from the start of the job.
TMTØGØ	Remaining CPU time in integer seconds based on the TIME card.
PREC	Returns the currently requested precision; single precision (1) or double precision (2).
DIAG	Turn on DIAGs IN1 through IN2. IN1 ≥ IN2 will turn on DIAG IN1 IN1 < IN2 will turn on DIAG IN1 through DIAG IN2
DIAGØFF	Turn off DIAGs IN1 through IN2 as used for DIAG.
SSST	Turns DIAG |ØUT| on if ØUT > 0. Turns DIAG ØUT off if ØUT ≤ 0.
SSSR	Saves DIAG IN1 in ØUT if IN1 ≥ 0. Restores DIAG |IN1| to ØUT if IN1 < 0.
STSR	Saves SYSTEM(IN1) in ØUT if IN1 ≥ 0. Restores SYSTEM(IN1) to ØUT if IN1 < 0. (SYSTEM(IN1) is the IN1-th word in /SYSTEM/ common block.)
SYSR	Saves SYSTEM(IN1) in ØUT.
SYST	Sets the value of both SYSTEM(IN1) and ØUT to IN2.

2. PARAM does its own SAVE; therefore a SAVE is not needed following the module.

VIII. EXAMPLES:

1. To change the sense of parameter NØXYZ (which may be useful for the CØND or EQUIV instructions):

   PARAM // C,N,NØT / V,N,XYZ / V,N,NØXYZ $ or
   PARAM // *NØT* / XYZ / NØXYZ $

   Alternatively, XYZ could have been set in the following way:

   PARAM // C,N,MPY / V,N,XYZ / V,N,NØXYZ / C,N,-1 $ or
   PARAM // *MPY* / XYZ / NØXYZ / -1 $

2. PARAM // C,N,IMPL / V,N,ABC / V,N,DEF / V,N,GHI $

3. To set the value of parameter P1 to 5 and save it for subsequent use:

   PARAM // C,N,NØP / V,N,P1=5 $ or
   PARAM // *NØP* / P1=5 $

4. To set parameter ABC to +1:

   PARAM // C,N,EQ / V,N,ABC / C,N,2 / C,N,-3 $ or
   PARAM // *EQ* / ABC / 2 / -3 $

5. To change the maximum number of lines of printed output:

   PARAM // C,N,SYST / V,N,DUM / C,N,14 / C,N,150000 $ or
   PARAM // *SYST* // 14 / 150000 $

   The 14th word in /SYSTEM/ common block is MXLINS whose default value is 20000, i.e., SYSTEM(14) = 20000. The equivalent operations to the PARAM examples shown above are to code SYSTEM(14) = 150000 or MXLINS = 150000 on the NASTRAN card or to use the Case Control card MAXLINES = 150000.

6. To turn on DIAGs 1 through 6:

   PARAM // C,N,DIAG / C,N, / C,N,1 / C,N,6 $ or
   PARAM // *DIAG* // 1 / 6 $

   This can also be done with the Executive Control card DIAG 1,2,3,4,5,6.

I. NAME: PARAML (Selects parameters from a list)

II. PURPOSE: To select parameters from a user input matrix or table.

III. DMAP CALLING SEQUENCE:

```
PARAML   INPUT // C,N,ØP / V,N,RECNØ / V,N,WØRDN /
         V,N,REAL1 / V,N,INTEG / V,N,REAL2 / V,N,BCD $
```

IV. INPUT DATA BLOCKS:

INPUT - Any matrix or table

V. OUTPUT DATA BLOCKS:

None.

VI. PARAMETERS:

ØP - Input-BCD-no default.

RECNØ - Input-integer-default = 1

WØRDN - Input-integer-default = 1

REAL1 - Output-real-default = 1.0

INTEG - Output-integer-default = 0

REAL2 - Output-real-default = 1.0

BCD - Output-BCD-default = blank

VII. REMARKS:

1. REAL1, INTEG, REAL2, and BCD will be set by the module whenever they are "V" type parameters.

2. RECNØ and WØRDN control the starting point, according to ØP.

   If ØP = DMI, RECNØ is the column number and WØRDN is the row number. If WØRDN > NRØW (the number of rows in the matrix), INTEG = NRØW and REAL1 = REAL2 = 0.0.

   If ØP = DTI, RECNØ is the record number and WØRDN is the word number.

   If ØP = NULL, INTEG = -1 if the sixth word of the matrix trailer, i.e., the matrix density, is zero.

   If ØP = PRESENCE, INTEG will be -1 if INPUT is purged.

   If ØP = TRAILER, WØRDN is output as the value of ith word of the matrix trailer where i is set by RECNØ in accordance with the following table.

RECNØ	TERM OF MATRIX TRAILER
1	Number of columns
2	Number of rows
3	Form of matrix
4	Type of matrix
5	Maximum number of nonzero terms in any column of the matrix
6	Matrix density

VIII. EXAMPLE:

Obtain the value in column 1, row 1 of a matrix.

```
PARAML    KGG//C,N,DMI/C,N,1/C,N,1/V,N,TERM $
```

I. NAME: PARAMR (Parameter Processor - Real)

II. PURPOSE: To perform specified arithmetic, logical, and conversion operations on real or complex parameters.

III. DMAP CALLING SEQUENCE:

```
PARAMR   // C,N,ØP / V,N,ØUTR / V,N,INR1 / V,N,INR2 /
                   V,N,ØUTC / V,N,INC1 / V,N,INC2 /
                   V,N,FLAG $
```

IV. INPUT DATA BLOCKS:

None.

V. OUTPUT DATA BLOCKS:

None.

VI. PARAMETERS:

ØP	-	Input-BCD operation code from the table below - no default
ØUTR	-	Output-real-default = 0.0
INR1	-	Input-real-default = 0.0
INR2	-	Input-real-default = 0.0
ØUTC	-	Output-complex-default = (0.0,0.0)
INC1	-	Input-complex-default = (0.0,0.0)
INC2	-	Input-complex-default = (0.0,0.0)
FLAG	-	Output-integer-default = 0

The values of the parameters are dependent upon ØP as shown in the following table:

ØP	OUTPUTS
ADD	ØUTR = INR1 + INR2
SUB	ØUTR = INR1 - INR2
MPY	ØUTR = INR1 * INR2
DIV	ØUTR = INR1 / INR2
NØP	RETURN
SQRT	ØUTR = $\sqrt{\text{INR1}}$
SIN	ØUTR = SIN(INR1)
CØS	ØUTR = CØS(INR1)
ABS	ØUTR = | INR1 |
EXP	ØUTR = exp (INR1)

TAN	ØUTR = TAN(INR1)
NØRM	ØUTR = || ØUTC ||
PØWER	ØUTR = INR1 ** INR2
ADDC	ØUTC = INC1 + INC2
SUBC	ØUTC = INC1 - INC2
MPYC	ØUTC = INC1 * INC2
DIVC	ØUTC = INC1 / INC2
CSQRT	ØUTC = $\sqrt{\text{INC1}}$
CØMPLEX	ØUTC = (INR1,INR2)
CØNJ	ØUTC = $\overline{\text{INC1}}$
REAL	INR1 = Re (ØUTC)
	INR2 = Im (ØUTC)
EQ	FLAG = -1 if INR1 = INR2
GT	FLAG = -1 if INR1 > INR2
LT	FLAG = -1 if INR1 < INR2
LE	FLAG = -1 if INR1 ≤ INR2
GE	FLAG = -1 if INR1 ≥ INR2
NE	FLAG = -1 if INR1 ≠ INR2
LØG	ØUTR = LØG_{10} (INR1)
LN	ØUTR = LØG_e (INR1)
FIX	FLAG = FIX (ØUTR)
FLØAT	ØUTR = FLØAT(FLAG)

VII. REMARKS:

1. Any output parameter must be "V" type if the parameter is used by "ØP" as output.
2. For ØP = DIV or ØP = DIVC, the output is zero if the denominator is zero.
3. PARAMR does its own SAVE; therefore, a SAVE is not needed following the module.
4. For ØP = SIN, ØP = CØS or ØP = TAN, the input must be expressed in radians.

I. NAME: PRTPARM (Parameter and DMAP Message Printer)

II. PURPØSE: A. Prints parameter values.
B. Prints DMAP messages.

III. DMAP CALLING SEQUENCE:

PRTPARM // C,N,a / C,N,b / C,N,c $

IV. INPUT DATA BLØCKS: None

V. ØUTPUT DATA BLØCKS: None

VI. PARAMETERS:

a - Integer value (no default value)

b - BCD value (default value = XXXXXXXX)

c - Integer value (default value = 0)

VII. METHØD:

A. As a parameter printer, use a = 0. There are two options:

1. b = parameter name will cause the printout of the value of that parameter.

Example: PRTPARM // C,N,0 / C,N,LUSET $

2. b = XXXXXXXX will cause the printout of the values of all parameters in the current variable parameter table. Since this is the default value, it need not be specified.

Example: PRTPARM // C,N,0 $

B. As a DMAP message printer, use $a \neq 0$. There are two options:

1. $a > 0$ causes the printout of the j^{th} message of category b where $j=|a|$ and b is one of the values shown below. (The number of messages available in each category is also given.)

Example: PRTPARM // C,N,1 / C,N,DMAP $

2. $a < 0$ causes the same action as $a > 0$ with the additional action of program termination. Thus, PRTPARM may be used as a fatal message printer.

Example: PRTPARM // C,N,-2 / C,N,PLA $

VIII. REMARKS:

1. b is always a value.

2. Meaningless values of a and b will result in diagnostic messages from PRTPARM.

3.

TABLE OF b CATEGORY VALUES

	DISPLACEMENT Rigid Formats	Value of b	Number of Messages
1	Static Analysis	STATICS	5
2	Static Analysis with Inertia Relief	INERTIA	6
3	Normal Mode Analysis	MODES	4
4	Static Analysis with Differential Stiffness	DIFFSTIF	5
5	Buckling Analysis	BUCKLING	6
6	Piecewise Linear Static Analysis	PLA	5
7	Direct Complex Eigenvalue Analysis	DIRCEAD	3
8	Direct Frequency and Random Response	DIRFRRD	4
9	Direct Transient Response	DIRTRD	3
10	Modal Complex Eigenvalue Analysis	MDLCEAD	5
11	Modal Frequency and Random Response	MDLFRRD	7
12	Modal Transient Response	MDLTRD	6
13	Normal Modes Analysis with Differential Stiffness	NMDSTIF	6
14	Static Analysis with Cyclic Symmetry	CYCSTAT	6
15	Normal Modes Analysis with Cyclic Symmetry	CYCMØDES	6
	HEAT Rigid Formats		
1	Static Heat Transfer	HSTAT	4
3	Nonlinear Static Heat Transfer	HNLIN	3
9	Transient Heat Transfer	HTRD	2
	AERØ Rigid Formats		
10	Modal Flutter Analysis	FLUTTER	5
11	Modal Aeroelastic Response	AERØRESP	4
	Direct Matrix Abstraction Program		
	DMAP	DMAP	See Remark 5

4. For details on error messages for the i^{th} Displacement Rigid Format, see Section 3.(i +1). The Heat and Aero Rigid Formats follow these.
5. The message number, a, may be any integer for DMAP messages.
6. The third parameter is not currently used.

DIRECT MATRIX ABSTRACTION

I. NAME: SCALAR (Convert matrix element to parameter)

II. PURPOSE: To extract a specified element from a matrix for use as a parameter.

III. DMAP CALLING SEQUENCE:

```
SCALAR   A//V,Y,NRØW=1/V,N,NCØL=1/C,Y,VALUE $
```

IV. INPUT DATA BLOCKS:

A - may be any type of matrix.

NOTE: If A is purged, value will be returned as (0.,0.).

V. OUTPUT DATA BLOCKS:

None

VI. PARAMETERS:

NRØW - Input-integer, default=1. Row number of element to be extracted from [A].

NCØL - Input-integer, default=1. Column identification of element.

VALUE - Output-complex-single precision, default=(0.,0.). Contents of element (NRØW,NCØL) in matrix [A].

I. NAME: SEEMAT (Pictorial Matrix Output)

II. PURPØSE: To display nonzero elements of a matrix on printer or plotter output positioned pictorially by row and column within the outlines of the matrix.

III. DMAP CALLING SEQUENCE:

```
SEEMAT  M1,M2,M3,M4,M5 // C,N,ØPTIØN/V,N,PFILE/V,N,PACK/
        C,N,MØDEL/C,N,TYPING/C,N,PAPERX/C,N,PAPERY $
```

IV. INPUT DATA BLØCKS:

M1,M2,M3,M4,M5 - Matrix data blocks any of which may be purged.

V. ØUTPUT DATA BLØCKS:

None

VI. PARAMETERS:

1. ØPTIØN - Input BCD value, default = PRINT. This parameter specifies the output option. PRINT implies the use of the system output file. PLØT implies the use of the NASTRAN General Purpose Plotter (NASTPLT) (see Section 4.1). (Any value other than PLØT implies PRINT.)

   Note: The following parameters are used only if ØPTIØN=PLØT.

2. PFILE - Input/Output-integer, default = 0. PFILE represents the frame (or sheet) number generated by the plotter. The value of this parameter is incremented by one (1) for each frame (or sheet) plotted by SEEMAT.

3. PACK - Input-integer, default = 100. Reserved for a future modification that will allow the representation of a nonzero block of a matrix with a single character.

4. MØDEL - Input-BCD value, default = M. This parameter specifies the plotter type or model. Permissible values are M (for microfilm plotters), T (for table plotters) and D (for drum plotters). The default value of M implies a microfilm plotter.

5. TYPING - Input-integer, default = 1. This parameter specifies the typing capability of the plotter. A value of 1 specifies a plotter without typing capability. (In this case, all characters in the plot will be drawn.) A value of 0 specifies a plotter with typing capability.

6. PAPERX - Input-real, default = 0.0. This parameter specifies the horizontal size (or X-dimension) (in inches) of the plot frame. The use of the default value of 0.0 actually causes the program to employ a horizontal size of 11.0 inches for table plotters and 30.0 inches for drum plotters. (PAPERX cannot be greater than 30.0 inches for table plotters.) See Remark 5 regarding the frame size for microfilm plotters.

7. PAPERY - Input-real, default = 0.0. This parameter specifies the vertical size (or Y-dimension) (in inches) of the plot frame. The use of the default value of 0.0 actually causes the program to employ a vertical size of 8.5 inches for table plotters and 30.0 inches for drum plotters. (PAPERY cannot be greater than 30.0 inches for either table or drum plotters.) See Remark 5 regarding the frame size for microfilm plotters.

VII. METHØD: The matrix is partitioned into blocks which can be printed on a single sheet of output paper or frame on the plotter selected. Only blocks containing nonzero elements will be output. Row and column indices are indicated. The user of this module is cautioned to

make sure his line count limit is large enough. A default of 20,000 lines is provided by NASTRAN. This may be changed by the use of the MAXLINES card in the Case Control Deck (see Section 2.3). The transpose of the matrix is output.

VIII. REMARKS:

1. If a plotter is used, the file PLT2 (either tape or mass storage area) must be made available to NASTRAN.

2. If a plotter is used, the PFILE parameter updated by SEEMAT must be saved either by using a SAVE instruction immediately after the SEEMAT instruction or by using the automatic SAVE feature (/S,N,PFILE/) in the SEEMAT instruction itself.

3. The nonzero elements are indicated by asterisks (*), except for diagonal elements of square matrices which are indicated by the letter D, and elements in the last row or column which are indicated by dollar signs ($).

4. The default plotter model is specified by omitting the last five parameters.

5. The plot frame size for microfilm plotters is set at 10.23 inches x 10.23 inches and is not under user control.

IX. EXAMPLES:

1. Specify a table plotter with typing capability as follows:

```
SEEMAT  M1,M2,M3,M4,M5 //*PLØT*/S,N,PFILE//*T*/0 $
```

2. Specify a drum plotter without typing capability as follows:

```
SEEMAT  M1,M2,M3,M4,M5 //*PLØT*/S,N,PFILE//*D* $
```

3. Specify the default plotter (a microfilm plotter without typing capability) as follows:

```
SEEMAT  M1,M2,M3,M4,M5 //*PLØT*/S,N,PFILE $
```

4. Specify the printer rather than a plotter as follows:

```
SEEMAT  M1,M2,M3,M4,M5 // $
```

5. For additional examples, see Section 5.8.8.

I. NAME: SETVAL (Set Values)

II. PURPØSE: Set DMAP Parameter variable values equal to other DMAP Parameter variables or DMAP Parameter constants.

III. DMAP CALLING SEQUENCE:

```
SETVAL  // V,N,X1 / V,N,A1 /
           V,N,X2 / V,N,A2 /
           V,N,X3 / V,N,A3 /
           V,N,X4 / V,N,A4 /
           V,N,X5 / V,N,A5 $
```

IV. INPUT DATA BLØCKS: None

V. ØUTPUT DATA BLØCKS: None

VI. PARAMETERS:

X1, X2, X3, X4, X5	Output, integers, variables
A1, A2, A3, A4, A5	Input, integers; default values = 1, variables or constants.

VII. METHØD: This module sets X1 = A1, X2 = A2, X3 = A3, X4 = A4, and X5 = A5. Only two parameters need be specified in the calling sequence (X1 and A1).

VIII. REMARKS:

1. A SAVE instruction must immediately follow the SETVAL instruction if the output parameter values are to be subsequently used.
2. See PARAM for an alternate method of defining parameter values.
3. As an example, the statements

```
SETVAL  // V,N,X1 / V,N,A1 / V,N,X2 / C,N,3 $
SAVE    X1,X2 $
```

are equivalent to the statements

```
PARAM  // C,N,ADD / V,N,X1 / V,N,A1 / C,N,0 $
PARAM  // C,N,NØP / V,N,X2=3 $
```

I. NAME: SWITCH

II. PURPOSE: To interchange two data block names.

III. DMAP CALLING SEQUENCE:

```
SWITCH  DB1,DB2 // PARAM  $
```

IV. INPUT DATA BLOCKS:

DB1 }
DB2 } Any NASTRAN data blocks

V. OUTPUT DATA BLOCKS: None

VI. PARAMETERS:

PARAM - If PARAM < 0 the switch will be performed - integer, input, default=-1.

VII. METHOD: If PARAM $\geq$ 0 a return is made, otherwise the names of the data blocks are interchanged. All attributes of the data within the blocks remains constant, only the names are changed.

VIII. REMARKS:

1. Neither input data block may be purged.
2. This option is of use in iterative DMAP operations.

I. NAME: TABPCH (Table Punch)

II. PURPOSE: To punch NASTRAN tables onto DTI cards in order to allow transfer of data from one NASTRAN run to another, or to allow user postprocessing.

III. DMAP CALLING SEQUENCE:

TABPCH TAB1,TAB2,TAB3,TAB4,TAB5 // C,N,A1 / C,N,A2 / C,N,A3 / C,N,A4 / C,N,A5 $

IV. INPUT DATA BLOCKS:

TAB1
TAB2
TAB3 Any NASTRAN Tables
TAB4
TAB5

V. OUTPUT DATA BLOCKS:

None - All output is punched onto DTI cards.

VI. PARAMETERS:

A1, A2, A3, A4, A5 -- Input - BCD - Defaults are 'AA', 'AB', 'AC', 'AD', 'AE'. These parameters are used to form the first two characters (columns 74, 75) of the continuation field for each table respectively.

VII. REMARKS:

1. Any or all tables may be purged.
2. Integer and BCD characters will be punched onto single-field cards. Real numbers will be punched onto double-field cards. Their formats are I8, 2A4, E16.9.
3. Up to 99,999 cards may be punched per table.
4. Currently, twice the entire record must fit in open core.
5. Tables with 1 word BCD values (ELSETS) cannot be punched correctly.

VIII. EXAMPLES:

TABPCH EST,,,, // C,N,ES $ will punch the EST onto cards with a continuation neumonic of $+ES_{bbbb}i$ (where i is the sequence number).

I. <u>NAME</u>: TABPRT (Formatted Table Printer)

II. <u>PURPOSE</u>: To print selected table data blocks with format for ease of reading.

III. <u>DMAP CALLING SEQUENCE</u>:

```
TABPRT    TDB // C,N,KEY / C,N,ØPT1 / C,N,ØPT2 $
```

IV. <u>INPUT DATA BLOCKS</u>:

TDB - Table Data Block from list given under X.

V. <u>ØUTPUT DATA BLOCKS</u>: None

VI. <u>PARAMETERS</u>:

1. KEY - Alphanumeric value, no default. Identifies the format to be used in printing the table. The allowable list is given under X.
2. ØPT1 - Integer, default value = 0. If 0, no blank lines are written between entires. If ≠ 0, one blank line will be written between each entry.
3. ØPT2 - Integer, default value = 0. Not used at present.

VII. <u>ØUTPUT</u>:

The contents of the table are formatted and written on the system output file.

VIII. <u>NØTES</u>:

1. The module returns in the event of any difficulty.
2. The TABPT module can be used to print the contents of <u>any</u> data block.

IX. <u>EXAMPLES</u>:

1. TABPRT CSTM // C,N,CSTM $
2. TABPRT GPL // C,N,GPL / C,N,1 $

X. MISCELLANEØUS

List of data blocks recognized by TABPRT (Rigid Format name used here. The actual DMAP name for the same or equivalent information is acceptable.)

Data Block	Key (Value)
BGPDT	BGPDT
CSTM	CSTM
EQDYN	EQDYN
EQEXIN	EQEXIN
GPCT	GPCT
GPDT	GPDT
GPL	GPL
GPLD	GPLD
GPTT	GPTT

I. NAME: TABPT (Table Printer)

II. PURPØSE: To print table data blocks (may be used for matrix data blocks if desired).

III. DMAP CALLING SEQUENCE:

TABPT TAB1,TAB2,TAB3,TAB4,TAB5 // $

IV. INPUT DATA BLØCKS:

TAB1 -
TAB2 -
TAB3 - Any NASTRAN data block.
TAB4 -
TAB5 -

Note: Any or all input data blocks can be purged.

V. ØUTPUT DATA BLØCKS: None

VI. PARAMETERS: None

VII. REMARKS:

1. Each input data block is treated as a table and its contents are printed on the system output file via a prescribed format. Each word of the table is identified by the module as to type (real, BCD, integer) and an appropriate format is used.
2. The trailer data items for the table are also printed.
3. Purged input data blocks are not printed.

VIII. EXAMPLES:

TABPT GEØM1,,,, // $
TABPT GEØM1,GEØM2,GEØM3,GEØM4,GEØM5 // $

I. NAME: TIMETEST (Provides Timing Data)

II. PURPOSE: To produce timing data for specific NASTRAN unit operations.

III. DMAP CALLING SEQUENCE:

```
TIMETEST  /, / C,N,N / C,N,M / C,N,T / C,N,Ø1 / C,N,Ø2 $
```

IV. INPUT DATA BLOCKS: None

V. OUTPUT DATA BLOCKS:

FILE1
FILE2 Reserved for future implementation

VI. PARAMETERS

N - Outer Loop Index

M - Inner Loop Index

T - Data type to be processed

Ø1 - TIMTST Routine to be processed

Ø2 - Powers of two table for TIMTS1 option selection

See Section 4.140 of the NASTRAN Programmer's Manual for further description of the parameters.

VII. REMARKS

None.

VIII. EXAMPLES

```
TIMETEST  / , / C,N,100 / C,N,100 / C,N,1 / C,N,2 $
TIMETEST  / , / C,N,10 / C,N,10 / C,N,3 / C,N,1 / C,N,127 $
```

DIRECT MATRIX ABSTRACTION

I. NAME: VEC (Creates partitioning vector based on USET).

II. PURPOSE: To create a partitioning vector for matrices using USET that may be used by Matrix Operation Modules MERGE and PARTN. This allows the user to split up long running modules such as SMP1.

III. DMAP CALLING SEQUENCE:

A. For matrices generated in Rigid Formats 1-6 or prior to module GKAD (or GKAM) in Rigid Formats 7-12:

VEC USET / V / C,N,SET / C,N,SETO / C,N,SET1 / V,N,ID $

B. For matrices generated in Rigid Formats 7-12 after module GKAD (or GKAM):

VEC USETD / V / C,N,SET / C,N,SETO / C,N,SET1 / V,N,ID $

IV. INPUT DATA BLOCKS:

USET - displacement set definition (statics)

or

USETD - displacement set definition (dynamics)

or

HUSET - displacement set definition (heat transfer)

or

USETA - displacement set definition (aeroelastic)

Note: The set definition input data block may not be missing and must fit into open core.

V. OUTPUT DATA BLOCKS:

V - Partitioning vector.

Note: 1. If all elements are in SETO or SET1 then V will be purged.
2. V may not be purged prior to execution.

VI. PARAMETERS:

SET - Matrix set to be partitioned (Input, BCD, no default).
SETO - Upper partition of SET (Input, BCD, no default).
SET1 - Lower partition of SET (Input, BCD, no default).
ID - Identification of bit position (see table below) (Input, integer, default = 0).

Note: 1. Legal parameter values are given in the table below.
2. See Section 1.4 for a description of set notation.

parameter value	USET matrix	bit position
M	U_m	32
S	U_s (union of SG and SB)	31
Ø	U_o	30

R	U_r	29
G	U_g	28
N	U_n	27
F	U_f	26
A	U_a	25
L	U_ℓ	24
SG	U_s (specified on Grid card)	23
SB	U_s (specified on SPC card)	22
E	U_e	21
P	U_p	20
NE	U_{ne} (union of N and E)	19
FE	U_{fe} (union of F and E)	18
D	U_d	17
PS	U_{ps}	16
SA	U_{sA}	15
K	U_k	14
PA	U_{pA}	13

VII. REMARKS:

1. Parameters SETO and SET1 must be a subset of the SET matrix parameter. A degree of freedom may not be in both subsets.
2. If desired, one of SETO or SET1 but not both may be requested to be the complement of the other one by giving it a value of CØMP.
3. If SET = BITID, the second and third parameters are ignored and the IDth bit position in USET (or USETD) is used. In this case, SET is assumed equal to G (or P) and SETO will correspond to the zero's in the IDth position and SET1 will correspond to the non-zer's in the IDth position.

VIII. EXAMPLES:

1. To partition $[K_{ff}]$ into a- and o- set based matrices, use

```
VEC   USET / V / C,N,F / C,N,Ø / C,N,A $
PARTN KFF,V, / KØØ,KAØ,KØA,KAA $
```

Note that the same thing can be done in one step by

```
UPARTN USET,KFF / KØØ,KAØ,KØA,KAA / C,N,F / C,N,P / C,N,A $
```

2. Example 1 could be accomplished by

```
VEC  USET / V / C,N,F / C,N,Ø / C,N,CØMP $
```

or

```
VEC  USET / V / C,N,F / C,N,CØMP / C,N,A $
```

3. Example 1 could be accomplished by

```
VEC  USET / V / C,N,BITID / C,N,X / C,N,X / C,N,25 $
```

5.6 USER MODULES

A number of modules have been placed in the NASTRAN system for which only dummy code exists. These modules are available to the user who wishes to create his own data blocks by reading tapes or data cards, generate his own output on the printer, punch or plotter, or perform his own matrix computations. The appropriate MPL (Module Properties List) information is presented for each such user module in this section. All necessary interfaces with the Executive System have been completed for these user modules. The procedures for implementing a user module are described in Section 6.12 of the Programmer's Manual.

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DIRECT MATRIX ABSTRACTION

I. NAME: DDR (User Dummy Module)

II. PURPØSE: Can be used for any desired purpose.

III. DMAP CALLING SEQUENCE: (see REMARKS below)

DDR A/X/C,N,ABC/C,N,DEF/C,N,GHI $

IV. INPUT DATA BLØCKS: As desired by author of module.

V. ØUTPUT DATA BLØCKS: As desired by author of module.

VI. PARAMETERS: Parameters may be used as desired by the author of the module. The parameter types are indicated by the constants shown in the calling sequence shown above.

VII. REMARKS:

This module has been provided for the user of NASTRAN who may wish to include a module of his own design into the system. The number of inputs and outputs, as well as the number, type, and default values of the parameters, may be changed by changing the Module Properties List (MPL) in subroutine XMPLDD (see Section 2 of the Programmer's Manual).

I. NAME: DUMMØD1 (Dummy Module - 1)

II. PURPØSE: Can be used for any desired purpose.

III. DMAP CALLING SEQUENCE: (see REMARKS)

```
DUMMØD1   I1,I2,I3,I4,I5,I6,I7,I8 /
          Ø1,Ø2,Ø3,Ø4,Ø5,Ø6,Ø7,Ø8 /
          C,N,-1 / V,Y,P2=-1 / V,N,P3=-1 / C,Y,P4=-1 /
          C,Y,P5=-1.0 / C,N,-1.0 /
          C,Y,P7=ABCDEFGH /
          C,Y,P8=-1.0D0 /
          C,Y,P9=(-1.0,-1.0) /
          C,Y,P10=(-1.0D0,-1.0D0) $
```

IV. INPUT DATA BLØCKS: As desired by author of module.

V. ØUTPUT DATA BLØCKS: As desired by author of module.

VI. PARAMETERS: Parameters may be used as desired by the author of the module. The parameter types are indicated by the default values shown in the calling sequence above.

VII. REMARKS: This module has been provided for the user of NASTRAN who may wish to include a module of his own design into the system. The number of inputs and outputs as well as the number, type, and default values of parameters may be changed by changing the Module Properties List (MPL) in subroutine XMPLDD (see Section 2 of the Programmer's Manual).

I. NAME: DUMMØD2 (Dummy Module - 2)

II. PURPØSE: Can be used for any desired purpose.

III. DMAP CALLING SEQUENCE: (see REMARKS)

```
DUMMØD2  I1,I2,I3,I4,I5,I6,I7,I8 /
         Ø1,Ø2,Ø3,Ø4,Ø5,Ø6,Ø7,Ø8 /
         C,N,-1 / V,Y,P2=-1 / V,N,P3=-1 / C,Y,P4=-1 /
         C,Y,P5=-1.0 / C,N,-1.0 /
         C,Y,P7=ABCDEFGH /
         C,Y,P8=-1.0D0 /
         C,Y,P9=(-1.0,-1.0) /
         C,Y,P10=(-1.0D0,-1.0D0) $
```

IV. INPUT DATA BLØCKS: As desired by author of module.

V. ØUTPUT DATA BLØCKS: As desired by author of module.

VI. PARAMETERS: Parameters may be used as desired by the author of the module. The parameter types are indicated by the default values shown in the calling sequence above.

VII. REMARKS: This module has been provided for the user of NASTRAN who may wish to include a module of his own design into the system. The number of inputs and outputs as well as the number, type, and default values of parameters may be changed by changing the Module Properties List (MPL) in subroutine XMPLDD (see Section 2 of the Programmer's Manual).

I. NAME: DUMMØD3 (Dummy Module - 3)

II. PURPØSE: Can be used for any desired purpose.

III. DMAP CALLING SEQUENCE: (see REMARKS)

```
DUMMØD3  I1,I2,I3,I4,I5,I6,I7,I8 /
         Ø1,Ø2,Ø3,Ø4,Ø5,Ø6,Ø7,Ø8 /
         C,N,-1 / V,Y,P2=-1 / V,N,P3=-1 / C,Y,P4=-1 /
         C,Y,P5=-1.0 / C,N,-1.0 /
         C,Y,P7=ABCDEFGH /
         C,Y,P8=-1.0D0 /
         C,Y,P9=(-1.0,-1.0) /
         C,Y,P10=(-1.0D0,-1.0D0) $
```

IV. INPUT DATA BLØCKS: As desired by author of module.

V. ØUTPUT DATA BLØCKS: As desired by author of module.

VI. PARAMETERS: Parameters may be used as desired by the author of the module. The parameter types are indicated by the default values shown in the calling sequence above.

VII. REMARKS: This module has been provided for the user of NASTRAN who may wish to include a module of his own design into the system. The number of inputs and outputs as well as the number, type, and default values of parameters may be changed by changing the Module Properties List (MPL) in subroutine XMPLDD (see Section 2 of the Programmer's Manual).

I. NAME: DUMMØD4 (Dummy Module - 4)

II. PURPØSE: Can be used for any desired purpose.

III. DMAP CALLING SEQUENCE: (see REMARKS)

```
DUMMØD4  I1,I2,I3,I4,I5,I6,I7,I8 /
         Ø1,Ø2,Ø3,Ø4,Ø5,Ø6,Ø7,Ø8 /
         C,N,-1 / V,Y,P2=-1 / V,N,P3=-1 / C,Y,P4=-1 /
         C,Y,P5=-1.0 / C,N,-1.0 /
         C,Y,P7=ABCDEFGH /
         C,Y,P8=-1.0D0 /
         C,Y,P9=(-1.0,-1.0) /
         C,Y,P10=(-1.0D0,-1.0D0) $
```

IV. INPUT DATA BLØCKS: As desired by author of module.

V. ØUTPUT DATA BLØCKS: As desired by author of module.

VI. PARAMETERS: Parameters may be used as desired by the author of the module. The parameter types are indicated by the default values shown in the calling sequence above.

VII. REMARKS: This module has been provided for the user of NASTRAN who may wish to include a module of his own design into the system. The number of inputs and outputs as well as the number, type, and default values of parameters may be changed by changing the Module Properties List (MPL) in subroutine XMPLDD (see Section 2 of the Programmer's Manual).

I. NAME: INPUTT3 (Auxiliary Input File Processor)

II. PURPØSE: A user-written module to generate data block(s) and parameter(s) based on input data read by the module itself, or on parameter values or Input Data Blocks generated by NASTRAN, or by any combination of these.

III. DMAP CALLING SEQUENCE:
INPUTT3 I1,I2,I3,I4,I5 / Ø1,Ø2,Ø3,Ø4,Ø5 / C,N,a / C,N,b / C,N,c $

IV. INPUT DATA BLØCKS: Any or all of the inputs may be purged according to the user-writer's design.

V. ØUTPUT DATA BLØCKS: May be tables or matrices depending on the user-writer's design; may or may not be purged.

VI. PARAMETERS: May be used as desired by the user-writer. Type is integer with default values of a=-1, b=0, c=0. If parameter is to be output from module, the form C,N,_ must be changed in the above example to V,N,NAME or some other form capable of being output.

VII. REMARKS: This module has been provided for the NASTRAN user who wishes to process his own data cards. Data block(s) created must be compatible with any subsequent module(s) using them as input. The number of input and output data blocks, as well as the number, type and default values of the parameters, may be changed by changing the Module Properties List (MPL) in subroutine XMPLDD (see Section 2 of the Programmer's Manual).

I. NAME: INPUTT4 (Auxiliary Input File Processor)

II. PURPØSE: A user-written module to generate data block(s) and parameter(s) based on input data read by the module itself, or on parameter values or Input Data Blocks generated by NASTRAN, or by any combination of these.

III. DMAP CALLING SEQUENCE:

INPUTT4 I1,I2,I3,I4,I5 / Ø1,Ø2,Ø3,Ø4,Ø5 / C,N,a / C,N,b / C,N,c $

IV. INPUT DATA BLØCKS: Any or all of the inputs may be purged according to the user-writer's design.

V. ØUTPUT DATA BLØCKS: May be tables or matrices depending on the user-writer's design; may or may not be purged.

VI. PARAMETERS: May be used as desired by the user-writer. Type is integer with default values of a=-1, b=0, c=0. If parameter is to be output from module, the form C,N,_ must be changed in the above example to V,N,NAME or some other form capable of being output.

VII. REMARKS: This module has been provided for the NASTRAN user who wishes to process his own data cards. Data block(s) created must be compatible with any subsequent module(s) using them as input. The number of input and output data blocks, as well as the number, type and default values of the parameters, may be changed by changing the Module Properties List (MPL) in subroutine XMPLDD (see Section 2 of the Programmer's Manual).

I. NAME: MATGEN (User Dummy Module)

II. PURPØSE: Can be used for any desired purpose.

III. DMAP CALLING SEQUENCE: (See REMARKS below)

PARTVEC I01,I02,---,I20,I21 / Ø1,Ø2,Ø3 / V,N,P1=0 / V,N,P2=0 / --- / V,N,P22=0 $

IV. INPUT DATA BLØCKS: As desired by author of module.

V. ØUTPUT DATA BLØCKS: As desired by author of module.

VI. PARAMETERS: Parameters may be used as desired by the author of the module. The parameter types are indicated by the values shown in the calling sequence shown above.

VII. REMARKS:

This module has been provided for the user of NASTRAN who may wish to include a module of his own design into the system. The number of inputs and outputs as well as the number, type, and default values of the parameters may be changed by changing the Module Properties List (MPL) in subroutine XMPLDD (see Section 2 of the Programmer's Manual).

I. NAME: MØDA (User Dummy Module)

II. PURPØSE: Can be used for any desired purpose.

III. DMAP CALLING SEQUENCE: (See REMARKS below)

```
MØDA  / W,X,Y,Z / C,N,0.0 / C,N,0.0 / C,N,0.0 / C,N,0.0 / C,N,0.0 / C,N,0 /
        C,N,0 / C,N,0 / C,N,0 / C,N,0 / C,N,0.0 / C,N,0 / C,N,0 $
```

IV. INPUT DATA BLØCKS: None

V. ØUTPUT DATA BLØCKS: As desired by author of module.

VI. PARAMETERS: Parameters may be used as desired by the author of the module. The parameter types are indicated by the constants shown in the calling sequence shown above.

VII. REMARKS: This module has been provided for the user of NASTRAN who may wish to include a module of his own design into the system. The number of inputs and outputs as well as the number, type, and default values of the parameters may be changed by changing the Module Properties List (MPL) in Block Data Program XMPLBD (see Section 2 of Programmer's Manual).

I. NAME: MØDB (User Dummy Module)

II. PURPØSE: Can be used for any desired purpose.

III. DMAP CALLING SEQUENCE: (See REMARKS below)

```
MØDB  A,B,C / W,X,Y,Z / C,N,1.0 / C,N,1.0 / C,N,1.0 / C,N,1.0 / C,N,0 / C,N,0 / C,N,0 /
            C,N,1.0 / C,N,0 / C,N,0 / C,N,0 $
```

IV. INPUT DATA BLØCKS: As desired by author of module.

V. ØUTPUT DATA BLØCKS: As desired by author of module.

VI. PARAMETERS: Parameters may be used as desired by the author of the module. The parameter types are indicated by the constants shown in the calling sequence shown above.

VII. REMARKS:

This module has been provided for the user of NASTRAN who may wish to include a module of his own design into the system. The number of inputs and outputs as well as the number, type, and default values of the parameters may be changed by changing the Module Properties List (MPL) in subroutine XMPLDD (see Section 2 of the Programmer's Manual).

DIRECT MATRIX ABSTRACTION

I. NAME: MØDC (User Dummy Module)

II. PURPØSE: Can be used for any desired purpose.

III. DMAP CALLING SEQUENCE: (See REMARKS below)

```
MØDC  A,B // C,N,-1 $
```

IV. INPUT DATA BLØCKS: As desired by author of module.

V. ØUTPUT DATA BLØCKS: None

VI. PARAMETERS: Parameters may be used as desired by the author of the module. The parameter types are indicated by the constants shown in the calling sequence shown above.

VII. REMARKS:

This module has been provided for the user of NASTRAN who may wish to include a module of his own design into the system. The number of inputs and outputs as well as the number, type, and default values of the parameters may be changed by changing the Module Properties List (MPL) in subroutine XMPLDD (see Section 2 of the Programmer's Manual).

I. NAME: ØUTPUT (Auxiliary Output File Processor)

II. PURPØSE: A user-written module to generate printer, plotter or punch output.

III. DMAP CALLING SEQUENCE: (see remark under METHØD)

ØUTPUT IN // C,Y,P=-1 $

IV. INPUT DATA BLØCKS:

IN - Contains any desired information which the module extracts and writes on the system output file, punch, or either of the two plotters. May be purged.

V. ØUTPUT DATA BLØCKS: None

VI. PARAMETERS: Parameters may be used as desired by the author of the module. Type is integer with MPL default value of -1 as shown above.

VII. METHØD: This module has been provided for the user of NASTRAN who may wish to process his own output. The number of inputs as well as the number, type, and default values of parameters may be changed by changing the Module Properties List (MPL) in subroutine XMPLDD (see Section 2 of the Programmer's Manual).

I. NAME: ØUTPUT4 (Auxiliary Output File Processor)

II. PURPØSE: A user-written module to generate printer, plotter or punch output.

III. DMAP CALLING SEQUENCE: (see remark under METHØD)

ØUTPUT4 IN1,IN2,IN3,IN4,IN5 // V,N,P1=-1 / V,N,P2=-1 $

IV. INPUT DATA BLØCKS:

INi - Contains any desired information which the module extracts and writes on the system output file, punch, or either of the two plotters. May be purged.

V. ØUTPUT DATA BLØCKS: None

VI. PARAMETERS: Parameters may be used as desired by the author of the module. Type is integer with MPL default value of -1 as shown above.

VII. METHØD: This module has been provided for the user of NASTRAN who may wish to process his own output. The number of inputs as well as the number, type, and default values of parameters may be changed by changing the Module Properties List (MPL) in subroutine XMPLDD (see Section 2 of the Programmer's Manual).

I. NAME: XYPRNPLT (User Dummy Module)

II. PURPØSE: Can be used for any desired purpose.

III. DMAP CALLING SEQUENCE: (see REMARKS below)

```
XYPRNPLT  A// $
```

IV. INPUT DATA BLØCKS: As desired by the author of module.

V. ØUTPUT DATA BLØCKS: None

VI. PARAMETERS: None

VII. REMARKS:

This module has been provided for the user of NASTRAN who may wish to include a module of his own design into the system. The number of inputs and outputs as well as the number, type, and default values of the parameters may be changed by changing the Module Properties List (MPL) in subroutine XMPLDD (see Section 2 of the Programmer's Manual).

5.7 EXECUTIVE OPERATION MODULES

All modules classified as Executive Operation Modules are individually described in this section. Additional discussions concerning the interaction of the Executive Modules with themselves and with the NASTRAN Executive Sustem are contained in Section 5.2.3.

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I. NAME: BEGIN (Begin DMAP Program)

II. PURPOSE: BEGIN is a declarative DMAP instruction which may be used to denote the beginning of a DMAP program.

III. DMAP CALLING SEQUENCE:

BEGIN $

IV. REMARKS:

1. BEGIN is a non-executable DMAP instruction which is used only by the DMAP compiler for information purposes.
2. Either a BEGIN card or an XDMAP card is required when selecting APP DMAP in the Executive Control Deck. This is followed by DMAP instructions up to and including the END card.
3. The use of BEGIN implicitly elects all compiler defaults. (See XDMAP instruction.)

I. NAME: CHKPNT (Checkpoint)

II. PURPOSE: Causes data blocks to be written on the New Problem Tape (NPTP) to enable the problem to be restarted with a minimum of redundant processing.

III. DMAP CALLING SEQUENCE:

CHKPNT D1,D2,...,DN $

where D1,D2,...,DN ($N \geq 1$) are data blocks to be copied onto the problem tape for use in restarting problem.

IV. RULES:

1. A data block to be checkpointed must have been referenced in a previous PURGE, EQUIV, or functional module instruction.
2. CHKPNT cannot be the first instruction of a DMAP loop.
3. Data Blocks generated by the Input File Processor (including DMI's and DTI's) should not be checkpointed since they are always regenerated on restart.
4. Checkpointing only takes place when a New Problem Tape (NPTP) is set up and the Executive Control Card CHKPNT YES appears in the Executive Control Deck. Otherwise, the CHKPNT instructions are ignored.
5. For each data block that is successfully checkpointed, a card o' the restart dictionary is punched which gives the critical data for the data block as it exists on the Problem Tape.
6. For data blocks that have been purged or equivalenced, an entry is made in the restart dictionary to this effect. In these cases data blocks are not written on the Problem Tape.

V. REMARKS:

1. See the PRECHK instruction for an automated CHKPNT capability.

I. NAME: CØMPØFF (Conditional DMAP Compilation Off)
(The companion module is CØMPØN)

II. PURPOSE: To allow blocks of DMAP statements to be compiled or skipped depending upon the value of a bulk data parameter.

III. DMAP CALLING SEQUENCE:

```
CØMPØFF LBLNAME,PARNAME $
        or
CØMPØFF c,PARNAME $
```

where:

1. LBLNAME is the BCD name of a label which specifies the end of the DMAP statement block,
2. c is an integer constant which specifies the number of DMAP statements in the block, and,
3. PARNAME is the name of a parameter that appears on a PARAM bulk data card.

IV. METHOD: The block of DMAP statements specified by the label or count is skipped if the value of the parameter is < 0. The block of DMAP statements will be compiled if the value of the parameter is ≥ 0.

V. EXAMPLE:

```
        .
        .
CØMPØFF LBL,NAM1 $
MØDULE1 A/B/L $
MØDULE2 C/D/M $
MØDULE3 E/F/N $
LABEL LBL $
        .
        .
        .
CØMPØFF 2,NAM2 $
MØDULE4 P/Q/I $
MØDULE5 X/Y/J $
        .
        .
```

In the above example, modules MØDULE1, MØDULE2 and MØDULE3 will not be compiled if the value of parameter NAM1 is < 0 and modules MØDULE4 and MØDULE5 will not be compiled if the value of parameter NAM2 is < 0.

(Continued)

COMPØFF (Cont.)

VI. REMARKS:

1. If no PARAM bulk data card is provided to define the parameter, a value of 0 is assumed.
2. If the form of CØMPØFF specifying a label is used, the label may not be referenced by any other DMAP instructions, including other CØMPØFF or CØMPØN instructions.
3. Comment cards are not included in the statement count.
4. CØMPØFF and CØMPØN instructions may be nested up to five levels using the same rules as for FØRTRAN DØ loops.

I. NAME: CØMPØN (Conditional DMAP Compilation On)
(The companion module is CØMPØFF)

II. PURPOSE: To allow blocks of DMAP statements to be compiled or skipped depending upon the value of a bulk data parameter.

III. DMAP CALLING SEQUENCE:

```
CØMPØN LBLNAME,PARNAME $
          or
CØMPØN c,PARNAME $
```

where:

1. LBLNAME is the BCD name of a label which specifies the end of the DMAP statement block,
2. c is an integer constant which specifies the number of DMAP statements in the block, and,
3. PARNAME is the name of a parameter that appears on a PARAM bulk data card.

IV. METHOD: The block of DMAP statements specified by the label or count is skipped if the value of the parameter is ≥ 0. The block of DMAP statements will be compiled if the value of the parameter is < 0.

V. EXAMPLE:

```
        .
        .
CØMPØN LBL,NAM1 $
MØDULE1 A/B/L $
MØDULE2 C/D/M $
MØDULE3 E/F/N $
LABEL LBL $
        .
        .
CØMPØN 2,NAM2 $
MØDULE4 P/Q/I $
MØDULE5 X/Y/J $
        .
        .
```

In the above example, modules MØDULE1, MØDULE2 and MØDULE3 will not be compiled if the value of parameter NAM1 is ≥ 0 and modules MØDULE4 and MØDULE5 will not be compiled if the value of parameter NAM2 is ≥ 0.

(Continued)

VI. REMARKS:

1. If no PARAM bulk data card is provided to define the parameter, a value of 0 is assumed.
2. If the form of COMPON specifying a label is used, the label may not be referenced by any other DMAP instructions, including other COMPON or COMPOFF instructions.
3. Comment cards are not included in the statement count.
4. COMPON and COMPOFF instructions may be nested up to five levels using the same rules as for FORTRAN DO loops.

I. NAME: CØND (Conditional Transfer)

II. PURPØSE: To alter the normal order of execution of DMAP modules by conditionally transferring program control to a specified location in the DMAP program.

III. DMAP CALLING SEQUENCE:

```
CØND  n,V $
```

where:

1. n is a BCD label name specifying the location where control is to be transferred. (See the LABEL instruction.)
2. V is a BCD name of a variable parameter whose value indicates whether or not to execute the transfer. If V < 0 the transfer is executed.

IV. EXAMPLE:

```
BEGIN $
  .
  .
  .
CØND  L1,K  $
MØDULE1  A/B/V,Y,P1  $
  .
  .
  .
LABEL  L1 $
MØDULEN  X/Y  $
  .
  .
  .
END $
```

If K ≥ 0, MØDULE1 is executed. If K < 0 control is transferred to the label L1 and MØDULEN is executed.

V. REMARKS:

Only forward transfers are allowed. See the REPT instruction for backward transfers.

I. NAME: END (End DMAP Program)

II. PURPØSE: Denotes the end of a DMAP program.

III. DMAP CALLING SEQUENCE:

```
END $
```

IV. NØTES:

1. The END instruction also acts as an implied EXIT instruction.
2. The END card is required whenever the analyst selects APP DMAP in his Executive Control Deck.

I. NAME: EQUIV (Data Block Name Equivalence)

II. PURPOSE: To attach one or more equivalent (alias) data block names to an existing data block so that the data block can be referenced by several equivalent names.

III. DMAP CALLING SEQUENCE:

EQUIV DBN1A,DBN2A,DBN3A / PARMA / DBN1B,DBN2B / PARMB $

Note: The number of data block names (DBNij) prior to each parameter (PARMj) and the number of such groups in a particular calling sequence are variable.

IV. INPUT DATA BLOCKS:

DBN1A,DBN2A, etc. - Any data block names appearing within the DMAP sequence. The 1st data block name in each group (DBN1A and DBN1B in the examples above) is known as the primary data block and the 2nd, etc. data block names become equivalent to the primary (depending on the associated parameter value). These equivalenced data blocks are known as secondary data blocks.

V. OUTPUT DATA BLOCKS: (None specified or permitted)

VI. PARAMETERS:

PARMA, etc. - One required for each set of data block names.

VII. METHOD: The data block names in each group are made equivalent if the value of the associated parameter is < 0. If a number of data blocks are already equivalenced and the parameter value is ≥ 0, the equivalence is broken and the data block names again become unique. If the data blocks are not equivalenced and the parameter value is ≥ 0, no action is taken.

VIII. REMARKS:

1. An EQUIV statement may appear at any time as long as the primary data block name has been previously defined.
2. If an equivalence is to be performed at all times, i.e., the parameter value is always negative, it is not necessary to specify a parameter name. For example,

EQUIV DB1,DB2 // DB3,DB4 $

I. NAME: EXIT (Terminate DMAP program)

II. PURPØSE: To conditionally terminate the execution of the DMAP program.

III. DMAP CALLING SEQUENCE:

EXIT c $

where c is an integer constant which specifies the number of times the instruction is to be ignored before terminating the program. If c = 0 the calling sequence may be shortened to EXIT $.

IV. EXAMPLE:

```
        BEGIN  $
          .
          .
          .
      /LABEL L1 $
     | MØDULE1 A/B/V,Y,P1 $
     |    .
DMAP  }   .
loop |    .
     | EXIT 3 $
      \REPT L1,3 $
          .
          .
          .
       END $
```

V. REMARKS:

1. The EXIT instruction will be executed the third time the loop is repeated (i.e., the instructions within the loop will be executed four times).
2. EXIT may appear anywhere within the DMAP sequence.

I. NAME: FILE (File Allocation Aide)

II. PURPØSE: To inform the File Allocator (see Section 4.9 of the Programmer's Manual) of any special characteristics of a data block.

III. DMAP CALLING SEQUENCE:

FILE A=a1,a2...aα / B=b1,b2...bβ / .... / Z=z1,z2...zω $

where:

A,B...Z are the names of the data blocks possessing special characteristics.

a1...aα,b1...bβ....z1...zω are the special characteristics from the list below.

The allowable special characteristics are:

1. SAVE - Indicates data block is to be saved for possible looping in DMAP program.
2. APPEND - Output data blocks which are generated within a DMAP loop are rewritten during each pass through the loop, unless the data block is declared APPEND in a FILE statement. The APPEND declaration allows a module to add information to a data block on successive passes through a DMAP loop.
3. TAPE - Indicates that data block is to be written on a physical tape if a physical tape is available.

Notes:

1. Data blocks created by the NASTRAN preface may not appear in FILE declarations.
2. Symbolic DMAP sequences which explain the use of the FILE instruction are given in Section 5.2.3.1.
3. FILE is a non-executable DMAP instruction which is used only by the DMAP compiler for information purposes.
4. A data block name may appear only once in all FILE statements; otherwise the first appearance will determine all special characteristics applied to the data block.

I. NAME: JUMP (Unconditional Transfer)

II. PURPØSE: To alter the normal order of execution of DMAP modules by unconditionally transferring program control to a specified location in the DMAP program. The normal order of execution of DMAP modules is the order of occurrence of the modules as DMAP instructions in the DMAP program.

III. DMAP CALLING SEQUENCE:

JUMP n $

where n is a BCD name appearing on a LABEL instruction which specifies where control is to be transferred.

IV. Remarks:

Jumps must be forward in the DMAP sequence. See the REPT instruction for backward jumps.

DIRECT MATRIX ABSTRACTION

I. NAME: LABEL (DMAP Location)

II. PURPØSE: To label a location in the DMAP program so that the location may be referenced by the DMAP instructions JUMP, CØND and REPT.

III. DMAP CALLING SEQUENCE:

LABEL n $

where n is a BCD name.

IV. Remarks:

1. The LABEL instruction is inserted just ahead of the DMAP instruction to be executed when transfer of control is made to the label.

2. LABEL is a non-executable DMAP instruction which is used only by the DMAP compiler for information purposes.

I. NAME: PRECHK (Predefined Automated Checkpoint)

II. PURPOSE: To allow the user to specify a single, or limited number, of checkpoint declarations thereby removing the need for a large number of individual CHKPNT instructions to appear in a DMAP program.

III. DMAP CALLING SEQUENCE:

PRECHK name list $

PRECHK ALL $

PRECHK ALL EXCEPT name list $

where name is a list of data block names separated by commas and not exceeding 50 data blocks per command .

IV. REMARKS:

1. PRECHK is, in itself, a non-executable DMAP instruction which actuates the automatic generation of explicity CHKPNT instructions during the DMAP compilation.
2. Any number of PRECHK declarations may appear in a DMAP program. Each time a new statement is encountered the previous one is invalidated. The PRECHK END $ option will negate the current PRECHK status.
3. CHKPNT instructions may be used in conjunction with PRECHK declarations. The CHKPNT instruction will override any PRECHK condition. For example, if the PRECHK ALL EXCEPT option is in effect, a data block named in the excepted list may still be explicitly CHKPNTed.
4. PRECHK automatically CHKPNTs all output data blocks from each functional module or purge instruction, and all secondary data block of an EQUIV instruction.

I. NAME: PURGE (Explicit Data Block Purge)

II. PURPOSE: To flag a data block so that it will not be assigned to a physical file.

III. DMAP CALLING SEQUENCE:

PURGE DBN1A,DBN2A,DBN3A / PARMA / DBN1B,DBN2B / PARMB $

Note: The number of data block names (DBN_{ij}) prior to each parameter ($PARM_j$) and the number of groups of data block names and parameters in a particular calling sequence is variable.

IV. INPUT DATA BLOCKS:

DBN1A,DBN2A, etc. - Any data block names appearing within the DMAP sequence.

V. OUTPUT DATA BLOCKS: (None specified or permitted)

VI. PARAMETERS:

PARMA, etc. - One required for each group of data block names.

VII. METHOD: The data blocks in a group are purged if the value of the associated parameter is < 0. If a data block is already purged and the parameter value is ≥ 0, the purged data block is unpurged so that it may be subsequently reallocated. If the data block is not purged and the parameter value is ≥ 0, no action is taken.

VIII. REMARKS:

1. If a purge is to be made at all times, i.e., the parameter value is always negative, it is not necessary to specify a parameter name. For example,

PURGE DB1,DB2,DB3,DB4 $

I. NAME: REPT (Repeat)

II. PURPOSE: To repeat a group of DMAP instructions a specified number of times.

III. DMAP CALLING SEQUENCE:

```
REPT  n,c  $    or   REPT  n,p  $
```

where:

1. n is a BCD name appearing in a LABEL instruction which specifies the location of the beginning of a group of DMAP instructions to be repeated. (See LABEL instruction.)
2. c is an integer constant hard coded into the DMAP program which specifies the number of times to repeat the instructions.
3. p is a variable parameter set by a previously executed module specifying the number of times to repeat the instructions.

IV. EXAMPLE:

```
BEGIN  $
  .
  .
  .
LABEL L1  $
MØDULE1 A/B/V,Y,P1  $
  .
  .
  .
MØDULEN B/C/V,Y,P2  $
REPT L1,3  $
  .
  .
  .
END  $
```

or

```
BEGIN  $
  .
  .
  .
MODULEI X/Y/V,Y,NLØØP  $
LABEL L1  $
MODULE1 A/B/V,Y,P1  $
  .
  .
  .
MODULE N B/C/V,Y,P2  $
REPT L1,NLØØP  $
  .
  .
  .
END  $
```

V. REMARKS:

1. REPT is placed at the end of the group of instructions to be repeated.
2. When a variable number of loops is to be performed as in the second example above, the value of the variable at the first time the REPT instruction is encountered will determine the number of loops. This number will not be changed after the initial assignment.
3. A CØND (conditional jump) instruction may be used to exit from the loop if desired.
4. In the first example, the instructions MØDULE1 to MØDULEN will be repeated three times (i.e., executed four times).

I. NAME: SAVE (Save Variable Parameter Values)

II. PURPOSE: To specify which variable parameter values are to be saved from the preceding functional module DMAP instruction for use by subsequent modules.

III. DMAP CALLING SEQUENCE:

SAVE V1,V2,...,VN $

where the V1,V2,...,VN (N > 0) are the BCD names of some or all of the variable parameters which appear in the immediately preceding Functional Module DMAP instruction.

IV. REMARKS:

1. A SAVE instruction must immediately follow the functional module instruction wherein the parameters being saved are generated.
2. See Section 5.2.1.5 for a description of the alternate method of saving parameter values by means of the parameter specification statement.

I. NAME: XDMAP (Execute DMAP Program)

II. PURPOSE: To control the DMAP compiler options.

III. DMAP CALLING SEQUENCE:

$$\text{XDMAP}\left\{\begin{array}{c}\underline{\text{GØ}}\\ \text{NØGØ}\end{array}\right\}, \left\{\begin{array}{l}\text{ERR = 0}\\ \text{ERR = 1}\\ \underline{\text{ERR = 2}}\end{array}\right\}, \left\{\begin{array}{c}\text{LIST}\\ \text{NØLIST}\end{array}\right\}, \left\{\begin{array}{c}\text{DECK}\\ \underline{\text{NØDECK}}\end{array}\right\}, \left\{\begin{array}{c}\text{ØSCAR}\\ \underline{\text{NØØSCAR}}\end{array}\right\}, \left\{\begin{array}{c}\text{REF}\\ \underline{\text{NØREF}}\end{array}\right\}$$

(see Remark 4 for default values)

where:

GØ - compile and execute program (default)

NØGØ - compile only and terminate job

ERR - defines the error level at which suspension of execution will occur:
ERR = 0 Warning level
= 1 Potentially fatal error level
= 2 Fatal error level (default)

LIST - a listing of the DMAP program will be printed
NØLIST - no listing
(see Remark 4 for default values)

DECK - a deck of the DMAP program will be punched

NØDECK - a deck will not be punched (default)

ØSCAR - detailed listing of ØSCAR (Operation Sequence Control Array), the output of the DMAP compiler

NØØSCAR - no ØSCAR listing (default)

REF - a cross reference listing of the DMAP program will be printed

NØREF - no cross reference listing (default)

IV. REMARKS:

1. The XDMAP card is optional and may be replaced by a BEGIN instruction. However, one or the other MUST appear in an APP DMAP execution.
2. The XDMAP instruction is non-executable and is used only to control the above options by the DMAP compiler.
3. If all defaults are chosen, this instruction need not appear and BEGIN may be used instead.
4. The DMAP compiler option is set to LIST for restart runs and for runs using the DMAP approach (APP DMAP) and the substructure capability (APP DISP,SUBS). The default is set to NØLIST for all other cases. (The NØLIST option should be used in the former cases in order to suppress the automatic listing of the DMAP program.)

(Continued)

XDMAP (Cont.)

5. Multiple XDMAP cards can be used in the DMAP to get subsets of the DMAP program to be listed (using the LIST/NØLIST option) or punched (using the DECK/NØDECK option).
6. The use of DIAGs in the Executive Control Deck (see Section 2.2) will always override the corresponding DMAP compiler options whether or not they are selected by means of an XDMAP card. Thus, the use of DIAG 4 will give the ØSCAR listing, DIAG 14 will give the DMAP program listing, DIAG 17 will give a punched output of the DMAP program and DIAG 25 will give the DMAP program cross-reference listing regardless of any other requests made by the presence or absence of XDMAP cards. The DMAP compiler option summary, printed before the DMAP source listing, reflects the DIAG selections, if any.

5.8 EXAMPLES

In order to facilitate the use of DMAP, several examples are provided in this section. The user is urged to study these examples both from the viewpoint of performing a sequence of matrix operations and that of a DMAP flow. In addition, some examples have been written to illustrate the improved DMAP syntax.

5.8.1 DMAP Example

Objective

1. Print the contents of table data block A.
2. Print matrix data blocks B, C, and D.
3. Print values of parameters P1 and P2.
4. Set parameter P3 equal to -7.

```
BEGIN      $
TABPT      A,,,, // $
MATPRN     B,C,D,, // $
PRTPARM    // C,N,0 / C,N,P1 $
PRTPARM    // C,N,0 / C,N,P2 $
PARAM      // C,N,NØP / V,N,P3=-7 $
END        $
```

```
XDMAP      $
TABPT      A // $
MATPRN     B,C,D // $
PRTPARM    // 0 / *P1* $
PRTPARM    // 0 / *P2* $
PARAM      // *NØP* / P3=-7 $
END        $
```

Remarks:

1. To be a practical example, a restart situation is assumed. The user is cautioned to remember to reenter at DMAP instruction 2 by changing the last reentry point in the restart dictionary.

2. In the alternate form, the omission of trailing commas in the TABPT and MATPRN instructions will generate PØTENTIALLY FATAL ERRØR messages alerting the user to possible errors in the data block name list.

5.8.2 DMAP Example

Let the constrained matrix $[K_{\ell\ell}]$ and the load vector $\{P_\ell\}$ be defined by means of DMI bulk data cards. The following DMAP sequence will perform the series of matrix operations

$$\{u_1\} = [K_{\ell\ell}]^{-1}\{P_\ell\}$$

$$\{r\} = [K_{\ell\ell}]\{u_1\} - \{P_\ell\}$$

$$\{\delta u\} = [K_{\ell\ell}]^{-1}\{r\}$$

$$\{u_2\} = \{u_1\} + \{\delta u\}$$

Print $\{u_2\}$

```
BEGIN   $                                          XDMAP   $
SØLVE   KLL,PL / U1 / C,N,1 / C,N,1 / C,N,1 / C,N,1 $    SØLVE   KLL,PL / U1 / 1 / 1 / 1 / 1 $
MPYAD   KLL,U1,PL / R / C,N,0 / C,N,1 / C,N,-1 $         MPYAD   KLL,U1,PL / R / 0 / 1 / -1 $
SØLVE   KLL,R / DU / C,N,1 $                       or    SØLVE   KLL,R / DU / 1 $
ADD     U1,DU / U2 $                                     ADD     U1,DU  /U2 $
MATPRN  U2,,,, // $                                      MATPRN  U2 // $
END     $                                                END     $
```

Remarks:

1. $[K_{\ell\ell}]$ is assumed symmetric.
2. In the example above, KLL will be decomposed twice. A more efficient DMAP sequence, which requires only a single decomposition for this problem is given below.

```
BEGIN   $                                                    XDMAP   $
DECØMP  KLL / LLL,ULL $                                      DECØMP  KLL / LLL,ULL $
FBS     LLL,ULL,PL / U1 / C,N,1 / C,N,1 / C,N,1 / C,N,1 $    FBS     LLL,ULL,PL / U1 / 1 / 1 / 1 / 1  $
MPYAD   KLL,U1,PL / R / C,N,0 / C,N,1 / C,N,-1 $             MPYAD   KLL,U1,PL / R / 0 / 1 / -1 $
FBS     LLL,ULL,R / DU $                                or   FBS     LLL,ULL,R / DU $
ADD     U1,DU / U2 $                                         ADD     U1,DU / U2 $
MATPRN  U2,,,, // $                                          MATPRN  U2 // $
END     $                                                    END     $
```

5.8.3 DMAP Example to Use the Structure Plotter to Generate Undeformed Plots of the Structural Model

```
BEGIN     $
GP1       GEØM1,GEØM2, / GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL / V,N,LUSET / V,N,NØCSTM / V,N,NØGPDT $
SAVE      LUSET $
GP2       GEØM2,EQEXIN / ECT $
PLTSET    PCDB,EQEXIN,ECT / PLTSETX,PLTPAR,GPSETS,ELSETS / V,N,NSIL / V,N,NPSET $
SAVE      NPSET,NSIL $
PRTMSG    PLTSETX // $
PARAM     // C,N,NØP / V,N,PLTFLG=1 $
PARAM     // C,N,NØP / V,N,PFILE=0 $
CØND      P1,NPSET $
PLØT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,, / PLØTX1 / V,N,NSIL / V,N,LUSET /
          V,N,NPSET / V,N,PLTFLG / V,N,PFILE $
SAVE      NPSET,PLTFLG,PFILE $
PRTMSG    PLØTX1 // $
LABEL     P1 $
PRTPARM   // C,N,0 $
END       $
```

Remarks:

1. GEØM1, GEØM2, PCDB and CASECC are generated by the Input File Processor.
2. PRTPARM is used to print all current variable parameter values.
3. This DMAP sequence contains several structurally oriented modules. This sequence of DMAP instructions is essentially identical with the section of each rigid format associated with the operation of the Structure Plot Request Packet of the Case Control Deck (contained in data block PCDB).

5.8.4 Example of DMAP to Print Eigenvectors Associated with any of the Modal Formulation Rigid Formats

```
BEGIN   $
ØFP     LAMA,ØEIGS,,,, // $
SDR1    USET,,PHIA,,,GØ,GM,,KFS,, / PHIG,,QG / C,N,1 / C,N,REIG $
SDR2    CASECC,CSTM,MPT,DIT,EQEXIN,SIL,,,BGPDT,LAMA,QG,PHIG,EST, / , ØQG1,ØPHIG,ØES1,ØEF1, /
        C,N,REIG $
ØFP     ØPHIG,ØQG1,ØEF1,ØES1,, // $
END     $
```

Remarks:

1. A restart from a successfully executed modal formulation is assumed.
2. This DMAP sequence contains several structurally oriented modules.

5.8.5 Example of DMAP Using a User-written Module

As an example of how a user might perform matrix operations of his own design, the following DMAP is provided. Functional modules MØDA, MØDB, and MØDC are assumed to be written by the user and added to the NASTRAN system, replacing dummy modules with the same names. A brief explanation of a problem for which this DMAP is applicable is given.

```
 1   BEGIN     $
 2   PARAM     // C,N,NØP / V,N,TRUE=-1 $
 3   PARAM     // C,N,NØP / V,N,FALSE=+1 $
 4   MØDA      / X,Y,DB,A / V,N,BETA=0.0 / V,N,SIGMA=1.0 / V,N,FW=0.0 / V,N,SW=0.0 /
               V,N,ETAINF=5.0 / V,N,M=100 / C,N,0 / C,N,0 / C,N,0 / V,N,ICØNV=0 /
               V,N,ZCØNV=1.0E-4 / V,N,ITMAX=10 / C,N,0 $
 5   SAVE      BETA,SIGMA,FW,SW,ETAINF,M,ICØNV,ZCØNV,ITMAX $
 6   LABEL     TØP $
 7   FILE      A=SAVE / DB=SAVE $
 8   SØLVE     A,DB / DY / C,N,0 / C,N,1 / C,N,1 / C,N,1 $
 9   EQUIV     X,XX / FALSE / Y,YY / FALSE $
10   MØDB      X,Y,DY / XX,YY,DBB,AA / V,N,BETA / V,N,SIGMA / V,N,FW / V,N,SW / V,N,M /
               C,N,0 / V,N,ICØNV / V,N,ZCØNV / C,N,0 / V,N,DØNE=1 / V,N,DIVERGED=1 $
11   SAVE      DØNE,DIVERGED $
12   CØND      QUIT,DIVERGED $
13   CØND      ØUT,DØNE $
14   EQUIV     XX,X / TRUE / YY,Y / TRUE / DBB,DB / TRUE / AA,A / TRUE $
15   CØND      QUIT,ITMAX $
16   REPT      TØP,1000 $
17   PRTPARM   // C,N,-1 / C,N,DMAP $
18   EXIT      $
19   LABEL     ØUT $
20   MØDC      X,Y // $
21   EXIT      $
22   LABEL     QUIT $
23   PRTPARM   // C,N,-2 / C,N,DMAP $
24   EXIT      $
25   END       $
```

The above DMAP sequence is designed to solve an iteration problem where {x} is the set of independent variable values on which the discretized solution {y(x)} is defined. Let the discrete values of {y(x)} measured at {x} be called {y}. An iteration sequence

$$\{y\}^{i+1} = \{y\}^i + [A(\{y\}^i,\{x\})]^{-1}\{\delta b(\{y\}^i,\{x\})\}$$

is to be performed where [A] and $\{\delta b\}$ are computable functions of $\{y\}$ and $\{x\}$. A convergence-divergence criterion is assumed known. It is also assumed that the independent variable distribution $\{x\}$ may be modified as the solution proceeds. A brief description of the significant DMAP instructions is given below:

4 Initialization of all parameters and output data blocks. This module is assumed to be written by the user.

7 Prevents file allocator from dropping A and DB.

8 Compute $\{\delta y\} = [A]^{-1}\{\delta b\}$

9 Break equivalences.

10 Iterate to obtain new $\{x\}$, $\{y\}$, $\{\delta b\}$, [A]; test convergence and set parameters DØNE and DIVERGED. This module is assumed to be written by the user.

14 The new $\{x\}$, $\{y\}$, $\{\delta b\}$, [A] are established as current by replacing the old values.

20 Prints out the converged solutions $\{x\}$ and $\{y\}$. This module is assumed to be written by the user.

5.8.6 DMAP ALTER Package for Using a User-Written Auxiliary Input File Processor

```
ALTER       1
INPUT       GEØM1,,,, / G1,,,G4, / C,N,3 $
PARAM       // C,N,NØP / V,N,TRUE=-1 $
EQUIV       G1,GEØM1 / TRUE / G4,GEØM4 / TRUE $
CØND        LBLXXX,TRUE $
TABPT       G1,G4,,, // $
LABEL       LBLXXX $
ENDALTER
```

Remarks:

1. This is an ALTER package that could be used by any Rigid Format.

2. The last three instructions are needed to avoid violating the Equivalence rule that a primary data block name must be referenced in a subsequent functional module. A way to avoid using these three instructions is to move the PARAM ahead of INPUT, in which case the EQUIV immediately follows the module in which the primary data blocks are output. In this case the ALTER package becomes

```
ALTER       1
PARAM       // C,N,NØP / V,N,TRUE=-1 $
INPUT       GEØM1,,,, / G1,,,G4, / C,N,3 $
EQUIV       G1,GEØM1 / TRUE / G4,GEØM4 / TRUE $
ENDALTER
```

3. It is assumed that a user-written module INPUT exists which reads data block GEØM1 (created by the Input File Processor of the NASTRAN Preface) and creates data blocks G1 and G4. It is then desired to use G1 and G4 in place of GEØM1 and GEØM4, the data blocks normally created by the NASTRAN Preface.

4. ALTER is described in Section 2.2.

5.8.7 DMAP to Perform Real Eigenvalue Analysis Using Direct Input Matrices

```
BEGIN    $
READ     KTEST,MTEST,,,DYNAMICS,,CASECC / LAMA,PHIA,MI,ØEIGS / C,N,MØDES / V,N,NE $
ØFP      LAMA,ØEIGS,,,, // $
MATPRN   PHIA,,,, // $
END      $
```

Notes:

1. The echo of a test problem bulk data deck for the preceding DMAP sequence follows.

```
.   1   ..   2   ..   3   ..   4   ..   5   ..   6   ..   7   ..   8   ..   9   ..  10   .
DMI     KTEST   0       6       1       2                       4       4
DMI     KTEST   1       1       200.0   -100.0
DMI     KTEST   2       1       -100.0  200.0   -100.0
DMI     KTEST   3       2       -100.0  200.0   -100.0
DMI     KTEST   4       3       -100.0  200.0
DMI     MTEST   0       6       1       2                       4       4
DMI     MTEST   1       1       1.0
DMI     MTEST   2       2       1.0
DMI     MTEST   3       3       1.0
DMI     MTEST   4       4       1.0
EIGR    1       INV     .0      2.5     2       2                               +1
+1      MAX
```

2. Data blocks DYNAMICS and CASECC are generated by the NASTRAN Preface (Input File Processor) and contain the eigenvalue extraction data from the EIGR card and the eigenvalue method selection data extracted from the METHØD card in the Case Control Deck.

3. Data blocks KTEST and MTEST are generated by the NASTRAN Preface (Input File Processor) from the DMI bulk data cards.

4. Data block MI is the modal mass matrix, which is not used in this DMAP subsequent to READ, but which must appear as an output in READ. Parameter NE is an output parameter whose value is the number of eigenvalues extracted. If none are found NE will be set to -1.

Alternate DMAP to perform real eigenvalue analysis using Direct Input Matrices where the degrees of freedom are associated with grid points.

EXAMPLES

```
BEGIN     $
GP1       GEØM1,GEØM2, / GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL / V,N,LUSET / C,N,0 / C,N,0 $
SAVE      LUSET $
GP4       CASECC,,EQEXIN,SIL,GPDT,BGPDT,CSTM / ,,USET, / V,N,LUSET / C,N,0 / C,N,0 /
          C,N,0 / C,N,0 / C,N,0 / C,N,0 / C,N,0 / C,N,0 / C,N,0 / C,N,0 $
DPD       DYNAMICS,GPL,SIL,USET / GPLD,SILD,USETD,,,,,,,EED,EQDYN / V,N,LUSET / C,N,0 /
          C,N,0 / C,N,0 / C,N,0 / C,N,0 / C,N,0 / C,N,0 / V,N,NØEED / C,N,0 / C,N,0 $
SAVE      NØEED $
CØND      E1,NØEED $
READ      KTEST,MTEST,,,EED,,CASECC / LAMA,PHIA,MI,ØEIGS / C,N,MØDES / V,N,NEIGV $
SAVE      NEIGV $
ØFP       LAMA,ØEIGS,,,, // $
CØND      FINIS,NEIGV $
SDR1      USET,,PHIA,,,,,,,, / PHIG,, / C,N,1 / C,N,REIG $
SDR2      CASECC,,,,EQEXIN,SIL,,,BGPDT,LAMA,,PHIG,,, / ,,ØPHIG,,, / C,N,REIG $
ØFP       ØPHIG,,,,, // $
JUMP      FINIS $
LABEL     E1 $
PRTPARM   // C,N,-2 / C,N,MØDES $
LABEL     FINIS $
END       $
```

Notes:

1. The echo of a test problem bulk data deck for the preceding DMAP sequence follows.

```
.   1   ..   2   ..   3   ..   4   ..   5   ..   6   ..   7   ..   8   ..   9   ..  10   .
DMI     KTEST   0       6               1       2                       4       4
DMI     KTEST   1       1               200.0   -100.0
DMI     KTEST   2       1               -100.0  200.0   -100.0
DMI     KTEST   3       2               -100.0  200.0   -100.0
DMI     KTEST   4       3               -100.0  200.0
DMI     MTEST   0       6               1       2                       4       4
DMI     MTEST   1       1               1.0
DMI     MTEST   2       2               1.0
DMI     MTEST   3       3               1.0
DMI     MTEST   4       4               1.0
EIGR    1       DET     .0              2.5     2       2                               +1
+1      MAX
SPØINT  1       THRU    4
```

2. Data block EED is generated by DPD, which copies the EIGR or EIGB cards from data block DYNAMICS. The actual card used is selected in case control by METHØD = SID.

3. Each degree-of-freedom defined by the DMI matrices must be associated with some grid or scalar point in this version. In the example above, this is done by defining four scalar points.

4. The EIGR card selected in the Case Control Deck will be used as explained in Note 2.

5. The use of module MTRXIN and DMIG bulk data cards will allow the user to input matrices via grid point identification numbers.

5.8.8 DMAP Example to Print and Plot a Topological Picture of Two Matrices

```
1. BEGIN     $
2. SEEMAT    KGG,KLL,,, // $
3. SEEMAT    KGG,KLL,,, //*PLØT*/S,N,P=0 $
4. PRTPARM   // 0 /*P* $
5. PARAM     // *MPY* /P/0/1 $
6. SEEMAT    KGG,KLL,,, //*PLØT*/S,N,P//*D*/0 $
7. PRTPARM   //0/*P* $
8. END       $
```

Notes:

1. Instruction number 2 causes the picture to be generated on the printer.

2. Instruction number 3 causes the picture to be generated on a microfilm plotter without typing capability (the default).

3. The parameter P is initialized to zero by instruction number 3. The form S,N,P would also have accomplished the same thing since the MPL default value is zero.

4. Instruction number 4 prints the current value of parameter P. Since P was initially set to zero and instruction number 3 is the first instruction executed which has P as an input, then P will have a zero value on input to instruction number 3. P is incremented by one (1) for every frame generated on the microfilm plotter. Since the value of the output parameter P was automatically saved, the value printed by instruction number 4 will be the number of frames generated by the execution of instruction number 3.

5. Instruction number 5 causes the value of P to be reset to zero (0), the product of zero (0) and one (1). Since PARAM is the only module which does its own SAVE, the parameter P need not be saved explicitly. This illustrates a commonly used technique for setting parameter values in DMAP programs.

6. Instructions 6 and 7 essentially repeat instructions 3 and 4 using a drum plotter with typing capability in place of a microfilm plotter without typing capability.

7. The END instruction, which is required, also acts as an EXIT instruction.

8. NASTRAN file PLT2 must be set up in order to execute this DMAP successfully.

9. Matrix data blocks KGG and KLL are assumed to exist on the PØØL file. This will be the case if either DMI input is used or if a restart is being made from a run in which KGG and KLL were generated and checkpointed.

5.8.9 DMAP Example to Compute the r-th Power of a Matrix [Q]

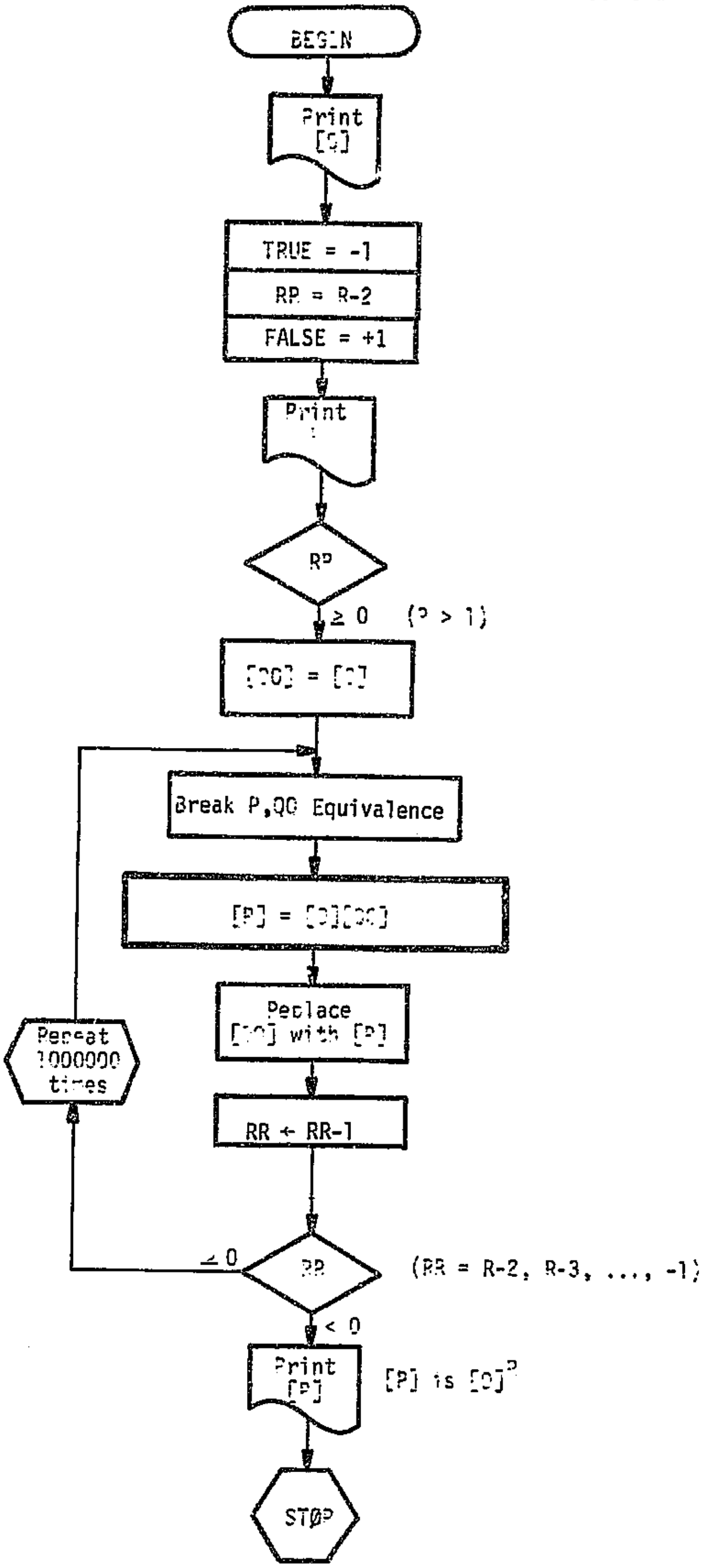
```
BEGIN       $
MATPRN      Q,,,, // $
PARAM       // C,N,NØP / V,N,TRUE=-1 $
PARAM       // C,N,SUB / V,N,RR / V,Y,R=-1 / C,N,2 $
PARAM       // C,N,NØP / V,N,FALSE=+1 $
ADD         Q, / QQ $
LABEL       DØIT $
EQUIV       QQ,P / FALSE $
MPYAD       Q,QQ, / P / C,N,0 $
EQUIV       P,QQ / TRUE $
PARAM       // C,N,SUB / V,N,RR / V,N,RR / C,N,1 $
CØND        STØP,RR $
REPT        DOIT,1000000 $
LABEL       STØP $
MATPRN      P,,,, // $
END         $
```

or

```
BEGIN       $
MATPRN      Q // $
PARAM       // *SUB* / RR / V,Y,R=-1 / 2 $
CØPY        Q / P $
LABEL       TØP $
MPYAD       Q,P / PP / 0 $
SWITCH      P,PP // $
REPT        TØP,RR $
MATPRN      P // $
END         $
```

Notes:

1. The matrix [Q] is assumed input via DMI bulk data cards.
2. The parameter R is assumed input on a PARAM bulk data card.
3. A logical flow diagram for this DMAP is shown in the following sketch.
4. The improved DMAP to perform the same operation can be done with substantially fewer commands.


BEGIN
Print
TRUE = -1
RR = R-2
FALSE = +1
Print
RR
≥ 0
(R > 1)
Break P,QQ Equivalence
Replace
with [P]
RR ← RR-1
Repeat
1000000
times
RR
(RR = R-2, R-3, ..., -1)
< 0
Print
[P]
STØP

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5.8.10 Usage of UPARTN, VEC and PARTN

In Rigid Format No. 7, the functional modules SMP1 and SMP2 (the latter used three times) together perform the following matrix operations:

$$[K_{ff}] \Rightarrow \left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right]$$

$$[G_o] = -[K_{oo}]^{-1} \; [K_{oa}]$$

$$[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}]^T \, [G_o]$$

$$[M_{ff}] \Rightarrow \left[\begin{array}{c|c} \bar{M}_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right]$$

$$[A] = [M_{oo}] \; [G_o] + [M_{oa}]$$

$$[B] = [M_{oa}]^T \; [G_o] + [\bar{M}_{aa}]$$

$$[M_{aa}] = [G_o]^T \; [A] + [B]$$

$$[K^4_{ff}] \Rightarrow \left[\begin{array}{c|c} \bar{K}^4_{aa} & K^4_{ao} \\ \hline K^4_{oa} & K^4_{oo} \end{array}\right]$$

$$[A] = [K^4_{oo}] \; [G_o] + [K^4_{oa}]$$

$$[B] = [K^4_{oa}]^T \; [G_o] + [\bar{K}^4_{aa}]$$

$$[K^4_{aa}] = [G_o]^T \; [A] + [B]$$

$$[B_{ff}] \Rightarrow \left[\begin{array}{c|c} \bar{B}_{aa} & B_{ao} \\ \hline B_{oa} & B_{oo} \end{array}\right]$$

$$[A] = [B_{oo}]\ [G_o] + [B_{oa}]$$

$$[B] = [B_{oa}]^T\ [G_o] + [\tilde{B}_{aa}]$$

$$[B_{aa}] = [G_o]^T\ [A] + [B]$$

This is far too many time-consuming matrix operations to perform within single modules when the a-set and o-set are large. (Remember, checkpoint only occurs <u>after</u> the module has done <u>all</u> its work.)

In order to subdivide the matrix operations, the partitions of the matrices $[K_{ff}]$ etc. must be obtained. The following ALTER packet accomplishes this objective by the use of the UPARTN module.

EXAMPLES

SMP1 and SMP2 using UPARTN for Rigid Format No. 7:

```
ALTER      n1,n2 $ (where n1 = DMAP statement number of the SMP1 module and n2 = DMAP
           statement number of the third use of the SMP2 module)
$
UPARTN     USET,KFF / KØØ, ,KØA,KAAB / *F*/*Ø*/*A* $
SØLVE      KØØ,KØA / GØ / 1 / -1 $
MPYAD      KØA,GØ,KAAB / KAA / 1 $
$
UPARTN     USET,MFF / MØØ, ,MØA,MAAB / *F*/*Ø*/*A* $
MPYAD      MØØ,GØ,MØA / MAATEMP1 / 0 $
MPYAD      MØA,GØ,MAAB / MAATEMP2/ 1 $
MPYAD      GØ,MAATEMP1,MAATEMP2 / MAA / 1 $
$
UPARTN     USET,K4FF / K4ØØ, ,K4ØA,K4AAB / *F*/*Ø*/*A*/ $
MPYAD      K4ØØ,GØ,K4ØA / K4AATMP1 / 0 $
MPYAD      K4ØA,GØ,K4AAB / K4AATMP2 / 1 $
MPYAD      GØ,K4AATMP1,K4AATMP2 / K4AA / 1 $
$
UPARTN     USET,BFF / BØØ, ,BØA,BAAB / *F*/*Ø*/*A* $
MPYAD      BØØ,GØ,BØA / BAATEMP1 / 0 $
MPYAD      BØA,GØ,BAAB / BAATEMP2 / 1 $
MPYAD      GØ,BAATEMP1,BAATEMP2 / BAA / 1 $
$
ENDALTER  $
```

The matrix operations can be further subdivided by making the partitioning information contained in USET available to the PARTN module. The following ALTER packet accomplishes this by the use of the VEC and PARTN modules.

SMP1 and SMP2 using VEC and PARTN for Rigid Format No. 7:

```
ALTER     n1,n2 $ (where n1 = DMAP statement number of the SMP1 module and n2 = DMAP
          statement number of the third use of the SMP2 module)
$
VEC       USET / V / *F*/*Ø*/*A* $
$
PARTN     KFF,V / KØØ, ,KØA,KAAB / $
DECØMP    KØØ / LØØ,UØØ / 1 / 0 / S,N,MIND / S,N,DET / S,N,NDET / S,N,SING $
CØND      LSING,SING $
FBS       LØØ,UØØ,KØA / GØ / 1 / -1 $
MPYAD     KØA,GØ,KAAB / KAA / 1 $
$
PARTN     MFF,V, / MØØ, ,MØA,MAAB $
MPYAD     MØØ,GØ,MØA / MAATEMP1 / 0 $
MPYAD     MØA,GØ,MAAB / MAATEMP2 / 1 $
MPYAD     GØ,MAATEMP1,MAATEMP2 / MAA / 1 $
$
PARTN     K4FF,V, / K4ØØ, ,K4ØA,K4AAB / $
MPYAD     K4ØØ,GØ,K4ØA / K4AATMP1 / 0 $
MPYAD     K4ØA,GØ,K4AAB / K4AATMP2 / 1 $
MPYAD     GØ,K4AATMP1,K4AATMP2 / K4AA / 1 $
$
PARTN     BFF,V, / BØØ, ,BØA,BAAB $
MPYAD     BØØ,GØ,BØA / BAATEMP1 / 0 $
MPYAD     BØA,GØ,BAAB / BAATEMP2 / 1 $
MPYAD     GØ,BAATEMP1,BAATEMP2 / BAA / 1 $
$
ALTER     n3 $ ADD ERRØR TRAP FØR SINGULAR KØØ MATRIX IN R.F. 7
          (n3 = DMAP statement number of JUMP FINIS)
$
LABEL     LSING $
```

EXAMPLES

```
PRTPARM   // 0 / *SING* $
PRTPARM   // -1 / *DMAP* $
EXIT      $
$
ENDALTER  $
```

5.8.11 DMAP Example

Let A, B and C be matrices whose values are to be defined at execution time. Let β be a real constant whose value is to be defined at execution time. Let α be an integer constant whose value (defined at execution time) determines the operations to be performed to compute matrix X as follows:

$$[X] = \begin{cases} [A][B] + [C] & , \alpha < 0 \\ \left[\beta[A] + [B]\right]^T & , \alpha = 0 \\ [A]^2[C]^{-1} & , \alpha > 0 \end{cases}$$

Write a DMAP to accomplish the above, assuming A, B and C will be defined by DMI bulk data cards and that α and β will be defined on PARAM bulk data cards. Print the inputs and outputs using the DMAP Utility Functional Modules MATPRN and PRTPARM. Use the DMAP Utility Module SEEMAT to print a topology display of [A] and [X].

A solution to this problem is given on the following page along with data for an actual example.

```
ID A,B
TIME 5
APP DMAP
BEGIN $
JUMP START $
PARAM // C,N,NØP / V,N,TRUE=-1 $  SET TRUE TØ -1 (=.TRUE.)
LABEL START $
MATPRN A,B,C,, // $
CØND ØNE,ALPHA $
PARAM // C,N,NØT / V,N,CHØØSE / V,Y,ALPHA $
CØND THREE,CHØØSE $
JUMP TWØ $
$
LABEL ØNE $                                                  ALPHA .LT. 0
MPYAD A,B,C / X / C,N,0 $
JUMP FINIS $
$
LABEL TWØ $                                                  ALPHA .EQ. 0
ADD A,B / Y / C,Y,BETA=(0.0,0.0) $
TRNSP Y / X2 $
EQUIV X2,X / TRUE $
JUMP FINIS $
$
LABEL THREE $                                                ALPHA .GT. 0
SØLVE C, / Z $
MPYAD A,Z, / W / C,N,0 $
MPYAD A,W, / X3 / C,N,0 $
EQUIV X3,X / TRUE $
$
LABEL FINIS $
MATPRN X,,,, // $
SEEMAT A,X,,, // C,N,PRINT $
PRTPARM // C,N,0 $
END $
CEND
TITLE = TEST MPYAD
BEGIN BULK
DMI      A       0       6       1       2               2       2
DMI      A       1       1       1.01
DMI      A       2       2       1.01
DMI      B       0       6       1       2               2       2
DMI      B       1       1       1.01
DMI      B       2       2       1.01
DMI      C       0       6       1       2               2       2
DMI      C       1       1       1.01
DMI      C       2       2       1.01
PARAM    ALPHA   -1
PARAM    BETA    1.0     .0
ENDDATA
```

5.9 AUTOMATIC SUBSTRUCTURE DMAP ALTERS

In the automated substructure process, the user commands (described in Section 2.7) are converted to the form of DMAP instructions via ALTER card equivalents. This section describes the resulting DMAP data for each command.

The "raw DMAP" data, stored in the program and modified according to the user input data, is listed by command type. The fields in the raw DMAP to be modified, or "variables", are underlined (i.e., XXX). The subcommand control cards are identified by parentheses on the right side. For example, the (P only) for the SUBSTRUCTURE command item 12, implies that this DMAP instruction is included only if the ØPTIØN request includes P (loads).

The ALTER card images are not true DMAP instructions but are used to locate positions in the existing DMAP Rigid Format for replacement by or insertion of the new DMAP instructions. The locations to be specified depend on the Rigid Format selected by the SØL Executive Control Card and are listed in Section 3 for each Rigid Format. The relevant section of the Rigid Format for each ALTER is indicated by the note in parentheses. For instance, "After GP4" in Rigid Format 1 (statics) implies "ALTER nn" (where nn is the DMAP instruction number of the GP4 module) for insertion of the corresponding DMAP instructions following Rigid Format 1 DMAP instruction number nn. If an existing set of DMAP instructions is to be removed, the parenthetical note may indicate "Remove DECØMP", where DECØMP may be a set of NASTRAN modules related to the entire decomposition process.

The descriptions given below are highly dependent on the user input commands and the Rigid Format selected. For an exact listing of all DMAP data generated for the current set of substructure commands, the DIAG 23 Executive Control Card may be input. Adding DIAG 24 will produce a punched deck of the actual ALTER cards generated. This feature allows the user to modify these ALTERs and execute under APP DMAP,SUBS.

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5.9.1 Index of Substructure DMAP ALTERs

DMAP for Command: BRECØVER (Phase 3)

The BRECØVER command converts the results of a Phase 2 substructure analysis to NASTRAN solution vectors for the detailed calculation of basic structure (or an equivalent basic substructure) displacements, forces, loads, and stresses. The same structure model of the primary substructure defined in Phase 1 must be used in Phase 3. It is possible to perform the Phase 3 execution either as a restart of the Phase 1 run or as an independent run, which recalculates the necessary data blocks.

Raw DMAP:

1	ALTER	(Remove solution)		
2	PARAM	//*NØP*/ALWAYS=-1 $		
3	SSG1	SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,CASECC,DIT/PG/LUSET/		(P or PA only)
4		NSKIP $ (R.F. 9 only)		(P or PA only)
5	SSG2	USET,GM,YS,KFS,GØ,,PG/QR,PØ,PS,PL $ (R.F. 1,2,3 or 9 only)		(P or PA only)
6	RCØVR3	,PG,PS,PØ,YS/UAS ,QAS,PGS,PSS,PØS,YSS,LAMA/SØLN/*NAME */		
7		NDUE $		
8	EQUIV	PGS,PG/ALWAYS $		
9	EQUIV	PSS,PS/ALWAYS $	(R.F. 1 or 2 only)	(P or PA only)
10	EQUIV	PØS,PØ/ALWAYS $	(R.F. 1 or 2 only)	(P or PA only)
11	EQUIV	YSS,YS/ALWAYS $	(R.F. 1 or 2 only)	(P or PA only)
12	CØND	LBSSTP,ØMIT $	(R.F. 1 or 2 only)	(P or PA only)
13	FBS	LØØ,,PØS/UØØV/1/1/PREC/0 $	(R.F. 1 or 2 only)	(P or PA only)
14	LABEL	LBSSTP $	(R.F. 1 or 2 only)	(P or PA only)
15	ØFP	LAMA,,,,,//CARDNØ $ (R.F. 3 only)		
16	ALTER	(After SDR1)		
17	UMERGE	USET,QAS,/QGS/*G*/*A*/*Ø* $		
18	ADD	QG ,QGS/QGT $		
19	EQUIV	QGT,QG /ALWAYS $		
20	EQUIV	CASECC,CASEXX/ALWAYS $	(R.F. 8 or 9 only)	
21	ALTER	(Remove repeat logic)	(R.F. 8 or 9 only)	

Variables:

YS,PØ = Remove if not P or PA, or if not R.F. 1 or 2

PG,PS = Remove if not P or PA, or if not R.F. 1, 2, or 9

		R.F. 1	2	3	8	9
UAS	=	ULV	ULV	PHIA	UDVF	UDVT
PGS	=	PGS	PGS			PPT
PSS	=	PSS	PSS			PST
LAMA	=			LAMA	PPF	TØL
QG	=	QG	QG	QG	QPC	QP

PØS = Remove if not P or PA, or if not R.F. 1, 2, or 3

SØLN = Rigid Format solution number

NAME = Name of basic Phase 1 substructure, corresponding to input data

NØUE = Remove if not R.F. 8 or 9

STP = Step number

PREC = Precision

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DMAP for Command: CØMBINE

The CØMBINE command initiates the process for combining several substructures defined on the SØF files. The CØMB1 module reads the control deck and the bulk data cards and builds the tables and transformation matrices for the combination structure. The CØMB2 module performs the matrix transformations using the matrices stored onthe SØF file or currently defined as NASTRAN data blocks. The resultant matrices are stored on the SØF file and retained as NASTRAN data blocks.

Raw DMAP:

```
CØMB1     CASECC,GEØM4//STP/S,N,DRY/*PVEC* $
CØND      LBSTP,DRY $
CØMB2     ,KN01,KN02,KN03,KN04,KN05,KN06,KN07/KNSC/S,N,DRY/*K*/*      */
          *NAME0001*/*NAME0002*/*NAME0003*/*NAME0004*/*NAME0005*/
          *NAME0006*/*NAME0007* $                                        (K only)
SØFØ      ,KNSC,,,,//S,N,DRY/*NAMEC    */*KMTX* $
CØMB2     ,MN01,MN02,MN03,MN04,MN05,MN06,MN07/MNSC/S,N,DRY/*M*/*      */
          *NAME0001*/*NAME0002*/*NAME0003*/*NAME0004*/*NAME0005*/
          *NAME0006*/*NAME0007* $                                        (M only)
SØFØ      ,MNSC,,,,//S,N,DRY/*NAMEC    */*MMTX* $
CØMB2     ,PN01,PN02,PN03,PN04,PN05,PN06,PN07/PNSC/S,N,DRY/*P*/*PVEC*/
          *NAME0001*/*NAME0002*/*NAME0003*/*NAME0004*/*NAME0005*/
          *NAME0006*/*NAME0007* $                                        (P or PA only)
SØFØ      ,PNSC,,,,//S,N,DRY/*NAMEC    */*PVEC $
CØMB2     ,BN01,BN02,BN03,BN04,BN05,BN06,BN07/BNSC/S,N,DRY/*B*/*      */
          *NAME0001*/*NAME0002*/*NAME0003*/*NAME0004*/*NAME0005*/
          *NAME0006*/*NAME0007* $                                        (B only)
SØFØ      ,BNSC,,,,//S,N,DRY/*NAMEC    */*BMTX* $
CØMB2     ,K4N01,K4N02,K4N03,K4N04,K4N05,K4N06,K4N07/K4NSC/S,N,DRY/*K4*/
          *    */*NAME0001*/*NAME0002*/*NAME0003*/*NAME0004*/*NAME0005*/
          *NAME0006*/*NAME0007* $                                        (K4 only)
SØFØ      ,K4NSC,,,,//S,N,DRY/*NAMEC    */*K4MX* $
LABEL     LBSTP $
LØDAPP    PNSC,//*NAMEC    */S,N,DRY $   (PA only)
```

Variables:

STP	= Step number
PVEC	= PVEC for P option, PAPP for PA option
N01,N02,...etc.	= Internal numbers for structures to be combined
NSC	= Internal number of combined structure
NAME0001,NAME0002,...,etc.	= Names of pseudostructures to be combined
NAMEC	= Name of combined structure

DMAP for Command: CREDUCE

The CREDUCE command performs a complex modal synthesis reduction for a component substructure. The resulting generalized coordinates for the reduced substructure will consist of selected boundary point displacements and generalized displacements of the eigenvectors. The MRED1 module produces dummy USET and EED data blocks for the execution of the eigenvector extraction procedure. The EQST data block is created for use by the CMRED2 module. The CMRED2 module performs the actual matrix reduction. Note that, because the number of modal degrees of freedom is a calculated value, the RUN=DRY option is not allowed for complex modal reduction.

Raw DMAP:

```
PARAM    //*NØP*/ALWAYS=-1 $
MRED1    CASECC,GEØM4,DYNAMICS,CSTM/USETR,EEDR,EQST,DMR/*NAMEA    */
         S,N,DRY/STP/S,N,NØFIX/S,N,SKIPM/*COMPLEX* $
CØND     LBM3STP,DRY $
SØFI     /KNØA,MNØA,PNØA,BNØA,K4NØA/S,N,DRY/*NAMEA    */*KMTX*/*MMTX*/
         *PVEC*/*BMTX*/*K4MX* $
CØND     LBM2STP,SKIPM $
EQUIV    KNØA,KFFX/NØFIX $   (K only)
EQUIV    MNØA,MFFX/NØFIX $   (M only)
EQUIV    BNØA,BFFX/NØFIX $   (B only)
EQUIV    K4NØA,K4FFX/NØFIX $   (K4 only)
CØND     LBM1STP,NØFIX $
SCE1     USETR,KNØA,MNØA,BNØA,K4NØA/KFFX,KFSX,KSSX,MFFX,BFFX,K4FFX $
LABEL    LBM1STP $
PARAMR   //*CØMPLEX*//1,0/GPARAM  /G $                        (Remove for
ADD      KFFX,K4FFX/KDD/G/(0,0,1,0) $                          option PA)
EQUIV    KDD,KFFX/ALWAYS $
CEAD     KFFX,BFFX,MFFX,EEDR,/PHIDR,CLAMA,ØCEIGS,PHIDL/NEIGVS $
ØFP      CLAMA,ØCEIGS,,,,// $
EQUIV    PHIDR,PHIFR/NØFIX $
EQUIV    PHIDL,PHIFL/NØFIX $
CØND     LBM2STP,NØFIX $
UMERGE   USETR,PHIDR,/PHIFR/*N*/*F*/*S* $
UMERGE   USETR,PHIDL,/PHIFL/*N*/*F*/*S* $
LABEL    LBM2STP $
CMRED2   CASECC,CLAMA,PHIFR,PHIFL,EQST,USETR,KNØA,MNØA,BNØA,K4NØA,PNØA/
         KNØB,MNØB,BNØB,K4NØB,PNØB,PØNØB/STP/S,N,DRY/*PVEC* $
LABEL    LBM3STP $
LØDAPP   PNØB,PØNØB//*NAMEB    */S,N,DRY $   (PA only)
CØND     FINIS,DRY $
```

Variables:

STP	= Step Number
PVEC	= PVEC for option P, PAPP for option PA
NAMEA	= Name of input substructure, A
NAMEB	= Name of output substructure, B
NØA	= Internal number of substructure A
NØB	= Internal number of substructure B
KFFX,KFSX,KSSX	= K only
MFFX	= M only
BFFX	= B only
K4FFX	= K4 only
CLAMA,PHIFR,PHIFL	= Remove for option PA

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DMAP for Utility Commands: DELETE, DESTRØY, EDIT, EQUIV, RENAME, SØFPRINT

Several internal operations of the SØF may be performed with the utility commands which create various calls to the SØFUT module. Each of the commands and associated data are inserted as parameters.

Raw DMAP:

```
1   SØFUT      //DRY/*NAME    */*ØPER*/ØPT/*NAME0002*/*PREF*/*ITM1*/*ITM2*/
2              *ITM3*/*ITM4*/*ITM5* $
```

Variables:

NAME = Name of substructure
ØPER = Operation to be performed (first four characters of command, i.e., EDIT)
ØPT = Integer option code
NAME0002 = Second substructure name for EQUIV and RENAME
PREF = Prefix for EQUIV operation
ITM1,ITM2, etc. = SØF data item names

The following chart describes the variables used for each command.

Command	NAME	ØPER	ØPT	NAME0002	PREF	ITM1, etc.
DELETE	X	X				X
DESTRØY	X	X				
EDIT	X	X	X			
EQUIV	X	X		X	X	
RENAME	X	X		X		
SØFPRINT	X	X	X			X

DMAP for Command: MREDUCE

The MREDUCE command performs a modal synthesis reduction for a component substructure. The resulting generalized coordinates for the reduced substructure will consist of selected boundary point displacements and generalized displacements of the modal coordinates. The MRED1 module produces dummy USET and EED data blocks for the execution of the mode extraction procedure. The EQST and DMR data blocks are created for use by the MRED2 module. The MRED2 module performs the actual matrix reduction. Note that, because the number of modal degrees of freedom is a calculated value, the RUN=DRY option is not allowed for modal reduction.

Raw DMAP:

```
MRED1     CASECC,GEØM4,DYNAMICS,CSTM/USETR,EEDR,EQST,DMR/*NAMEA    */
          S,N,DRY/STP/S,N,NØFIX/S,N,SKIPM/*REAL* $
CØND      LBM3STP,DRY $
SØFI      /KNØA,MNØA,PNØA,BNØA,K4NØA/S,N,DRY/*NAMEA    */*KMTX*/*MMTX*/
          *PVEC*/*BMTX*/*K4MX* $
CØND      LBM2STP,SKIPM $
EQUIV     KNØA,KFFX/NØFIX $   (K only)
EQUIV     MNØA,MFFX/NØFIX $   (M only)
EQUIV     BNØA,BFFX/NØFIX $   (B only)
EQUIV     K4NØA,K4FFX/NØFIX $   (K4 only)
CØND      LBM1STP,NØFIX $
SCE1      USETR,KNØA,MNØA,BNØA,K4NØA/KFFX,KFSX,KSSX,MFFX,BFFX,K4FFX $
LABEL     LBM1STP $                                                        (Remove
READ      KFFX,MFFX,BFFX,K4FFX,EEDR,USETR,/LAMAR,PHIR,MIR,ØEIGR/*MØDES*/    for PA)
          NEIGVS $
ØFP       LAMAR,ØEIGR,,,,// $
EQUIV     PHIR,PHIS/NØFIX $
CØND      LBM2STP,NØFIX $
UMERGE    USETR,PHIR,/PHIS/*N*/*F*/*S* $
LABEL     LBM2STP $
MRED2     CASECC,LAMAR,PHIS,EQST,USETR,KNØA,MNØA,BNØA,K4NØA,PNØA,DMR,
          QSM/KNØB,MNØB,BNØB,K4NØB,PNØB,PØNØB/STP/S,N,DRY/*PVEC* $
LABEL     LBM3STP $
LØDAPP    PNØB,PØNØB//*NAMEB    */S,N,DRY $    (PA only)
CØND      FINIS,DRY $
```

AUTOMATIC SUBSTRUCTURE DMAP ALTERS

Variables:

STP	= Step number
PVEC	= PVEC for option P, PAPP for option PA
NAMEA	= Name of input substructure , A
NAMEB	= Name of output substructure , B
NØA	= Internal number of substructure A
NØB	= Internal number of substructure B
KFFX,KFSX,KSSX	= K only
MFFX	= M only
BFFX	= B only
K4FFX	= K4 only
LAMAR,PHIS	= Remove for option PA
QSM	= Remove for R.F. 9

DMAP for Substructure Plots: PLØT

Any level of substructure may be plotted as an undeformed shape using the existing NASTRAN plot logic. The plot sets generated in Phase 1 are combined and transformed for that plotting.

Raw DMAP:

```
1   PLTMRG    CASECC,PCDB/PLTSTP,GPSTP,ELSTP,BGSTP,CASSTP,EQSTP/*NAME    */
2             S,N,NGP/S,N,LSIL/S,N,NPSET $
3   SETVAL    //S,N,PLTFLG/1/S,N,PFIL/0 $
4   PLØT      PLTSTP,GPSTP,ELSTP,CASSTP,BGSTP,EQSTP,,,,,/PMSTP/NGP/LSIL/
5             S,N,NPSET/S,N,PLTFLG/S,N,PFIL $
6   PRTMSG    PMSTP// $
```

Variables:

NAME = Name of substructure to be plotted

STP = Step number

DMAP for Commands: RECØVER (Phase 2), MRECØVER (Phase 1, 2)

RECØVER performs the recovery and output of the Phase 2 solution data. MRECOVER performs the recovery and output subsequent to a Phase 1 or 2 MREDUCE or CREDUCE operation. The NASTRAN solution displacement vector (either displacement vectors or eigenvectors) is transformed and expanded to correspond to the degrees of freedom of the selected component substructures. Each pass through the DMAP loop corresponds to a requested structure to be processed. The RCØVR module selects the substructure to be processed with the loop counter, ILØØP.

Raw DMAP:

```
FILE     U1=APPEND/U2=APPEND/U3=APPEND/U4=APPEND/U5=APPEND $
PARAM    //*ADD*/ILØØP/0/0 $
LABEL    LBSTP $
RCØVR    CASESS,GEØM4,KGG,MGG,PGG,UGV,DIT,DLT,BGG,K4GG,PPF/ØUGV1
         ØPG1,ØQG1,U1,U2,U3,U4,U5/S,N,DRY/S,N,ILØØP/STP/*NAMEFSS */
         NSØL/NEIGV/S,N,LUI/S,N,U1N/S,N,U2N/S,N,U3N/S,N,U4N/S,N,U5N/
         S,N,NØSØRT2/V,Y,UTHRESH/V,Y,PTHRESH/V,Y,QTHRESH $
EQUIV    ØUGV1 ,ØUGV /NØSØRT2/ØQG1,ØQG/NØSØRT2 $
EQUIV    ØPG1,ØPG/NØSØRT2 $   (R.F. 1, 2, 8, or 9 only)
CØND     NST2STP,NØSORT2 $
SDR3     ØUGV1 ,ØPG1,ØQG1,,,/ØUGV ,ØPG,ØQG,,, $
LABEL    NST2STP $
ØFP      ØUGV ,ØPG,ØQG,,,//S,N,CARDNØ $
CØND     LBBSTP,ILØØP $
REPT     LBSTP,100 $
LABEL    LBBSTP $
SØFØ     ,U1,U2,U3,U4,U5//-1/*XXXXXXXX* $
```


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Variables:

KGG = K option only
MGG = M option only
BGG = B option only
K4GG = K4 option only

		R.F.	1	2	3	8	9
GEØM4	=		GEØM4	GEØM4	LAMA	GEØM4	GEØM4
PGG	=		PGG	PGG		PPF	PPT
UGV	=		UGV	UGV	PHIG	UGV	UGV
PPF	=					PPF	TØL
ØUGV1	=		ØUGV1	ØUGV1	ØPHIG1	ØUGV1	ØUGV1
ØUGV	=		ØUGV	ØUGV	ØPHIG	ØUGV	ØUGV

SS = SS or CC (if after SØLVE step)
DIT,DLT = Remove if not R.F. 1, 2, or 3
ØPG1,ØPG = Remove if R.F. 3
NSØL = Rigid Format solution number
NEIGV = R.F. 3 only
NAMEFSS = Name of solution structure

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DMAP for Command: REDUCE

The REDUCE command initiates the matrix partitioning operations to be performed on the stiffness, mass, damping, and load vectors in order to produce a set of matrices defined by a subset of the original degrees of freedom. The REDUCE module generates the partitioning vector PV, a USET data block US, and an identity matrix IN from the bulk data and the corresponding substructure tables stored on the SØF. The remainder of the DMAP sequence directs the actual matrix operations.

Raw DMAP:

```
REDUCE    CASECC,GEØM4/PVNØA,USSTP,INSTP/STP/S,N,DRY/*PVEC* $
CØND      LBRSTP,DRY $
SØFI      /KNØA,MNØA,PNØA,BNØA,K4NØA/S,N,DRY/*NAME000A*/*KMTX*/*MMTX*/
          *PVEC*/*BMTX*/*K4MX* $
CØND      LBRSTP,DRY $
SMP1      USSTP,KNØA,,,/GØNØA,KNØB,KØNØA,LØNØA,,,,, $
MERGE     GØNØA,INSTP,,,,PVNØA/GNØA/1/TYP/2 $                          (K only)
SØFØ      ,GNØA,LONØA,,,//DRY/*NAME000A*/*HØRG*/*LMTX* $
SØFØ      ,KNØB,,,,//DRY/*NAME000B*/*KMTX* $
SØFI      /GNØA,,,,/S,N,DRY/*NAME000A*/*HØRG* $   (all except K)
MPY3      GNØA,MNØA,/MNØB/0/0 $                                        (M only)
SØFØ      ,MNØB,,,,//DRY/*NAME000B*/*MMTX* $
MPY3      GNØA,BNØA,/BNØB/0/0 $                                        (B only)
SØFØ      ,BNØB,,,,//DRY/*NAME000B*/*BMTX* $
MPY3      GNØA,K4NØA,/K4NØB/0/0 $                                      (K4 only)
SØFØ      ,K4NØB,,,,//DRY/*NAME000B*/*K4MX* $
PARTN     PNØA,,PVNØA/PØNØA,,,/1/1/2 $
MPYAD     GNØA,PNØA,/PNØB/1/1/0/1 $                                    (P or PA only)
SØFØ      ,PØNØA,,,,//DRY/*NAME000A*/*PØVE* $
SØFØ      ,PVNØA,,,,//DRY/*NAME000A*/*UPRT* $
SØFØ      ,PNØB,,,,//DRY/*NAME000B*/*PVEC* $   (P or PA only)
LABEL     LBRSTP $
LØDAPP    PNØB,PØNØA//*NAME000B*/S,N,DRY $   (PA only)
```

Variables:

STP	= Step number
NAME000A	= Name of input structure, A
NAME000B	= Name of output structure, B
NØA,NØB	= Internal numbers of substructures A and B
TYP	= Matrix precision flag (1 = single)
PVEC	= PVEC for P option, PAPP for PA option
PØVE	= PØVE for P option, PØAP for PA option

AUTOMATIC SUBSTRUCTURE DMAP ALTERS

DMAP for Command: RUN

The RUN command defines the DRY parameter for use by the subsequent DMAP instructions. If the user specifies RUN=DRYGØ, a special set of DMAP instructions are placed at the end of the entire command sequence.

Raw DMAP:

```
    PARAM        //*ADD*/DRY/I  /0$
```

Variables:

I = Integer code for RUN option (DRY = -1, GØ = 0, STEP = 1)

If RUN=DRYGØ, I is set to (DRY) initially and the following DMAP is inserted at the end of the complete ALTER stream:

```
LABEL        LBSEND $
PARAM        //*ADD*/DRY/DRY/1 $
CØND         FINIS,DRY $
REPT         LBSBEG,1 $
JUMP         FINIS $
```

DMAP for External I/Ø Commands: SØFIN, SØFØUT, RESTØRE, DUMP, CHECK

Several operations may be performed on the NASTRAN user files and the SØF file using the EXIØ module. The various input parameters are set by the Substructure Commands.

Raw DMAP:

```
EXIØ     //S,N,DRY/MACH/*DEVI*/*UNITNAME*/*FØRM*/*MØDE*/*PØSI*/*ITEM*/
         *NAME0001*/*NAME0002*/*NAME0003*/*NAME0004*/*NAME0005* $
```

Variables:

MØDE	= First four characters of command name (i.e., 'SØFI', 'REST')
DEVI	= Device used for I/Ø file ('TAPE' or 'DISK')
UNITNAME	= Name of NASTRAN user file assigned to I/Ø file (i.e., INPT, INP1, etc.)
FØRM	= Format of data ('EXTE' or 'INTE')
PØSI	= Position of file on device ('REWI', 'NØRE', or 'EØF')
ITEM	= Name of SØF item or 'ALL', 'MATR', 'TABL', or 'PHAS'
NAME0001, etc.	= Names of substructures to be copied

The following chart describes the variables used for each command:

Command	MØDE	DEVI	UNITNAME	FØRM	PØSI	ITEM	$NAME000_i$
SØFIN	X	X	X	X	X	X	X
SØFØUT	X	X	X	X	X	X	X
RESTØRE	X	X	X				
DUMP	X	X	X				
CHECK	X	X	X				

DMAP for Command: SØLVE

The SØLVE command provides the necessary data for execution of the solution phase of NASTRAN. Module SGEN replaces the NASTRAN GP1 module for the purpose of defining an equivalent pseudostructure from data blocks. The new data blocks GE3S and GE4S contain the load and constraint data in the form of converted bulk data card images. The stiffness, mass, viscous damping, and structural damping matrices are obtained from the SØF files and added to any user matrix terms. The static and dynamic analysis rigid formats require separate raw DMAP. Both sets of raw DMAP are shown below.

Raw DMAP, Rigid Formats 1-3

```
ALTER      (Remove GP1)
PARAM      //*NØP*/ALWAYS=-1 $
SGEN       CASECC,GEØM3,GEØM4,DYNAMICS/CASESS,CASEI,GPL,EQUEXIN,GPDT,
           BGPDT,SIL,GE3S,GE4S,DYNS/S,N,DRY/*NAMESØLS*/S,N,LUSET/
           S,N,NØGPDT $
PURGE      CSTM $
EQUIV      GE3S,GEØM3/ALWAYS/GE4S,GEØM4/ALWAYS/CASEI,CASECC/ALWAYS/
           DYNS,DYNAMICS/ALWAYS $
CØND       LBSTP,DRY $
ALTER      (Remove PLØT)
ALTER      (Remove NØSIMP CØND)
CØND       LBSØL,NØSIMP $
ALTER      (Remove Property Øptimization EQUIV or NØMGG CØND)
CØND       LBSØL,NØMGG $
ALTER      (Remove SMA3)
LABEL      LBSØL $
SØFI       /KNØS,MNØS,,,/DRY/*NAMESØLS*/*KMTX*/*MMTX* $
EQUIV      KNØS,KGG/NØSIMP $   (K only)
EQUIV      MNØS,MGG/NØSIMP $   (M only)
CØND       LBSTP,NØSIMP $
ADD        KGGX,KNØS/KGG $   (K only)
ADD        MGG,MNØS/MGGX $   (M only)
EQUIV      MGGX,MGG/ALWAYS $
LABEL      LBSTP $
CHKPNT     MGG $
ALTER      (After GP4)
CØND       LBSEND,DRY $
ALTER      (Remove SDR2 - PLØT)
```


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DIRECT MATRIX ABSTRACTION

Variables:

NAMESØLS	=	Name of solution structure
NØS	=	Internal number of solution structure
STP	=	Step number

Raw DMAP, Rigid Formats 8, 9

```
ALTER     (Remove GP1)
PARAM     //*NØP*/ALWAYS=-1 $
SGEN      CASECC,GEØM3,GEØM4,DYNAMICS/CASESS,CASEI,GPL,EQEXIN,GPDT,
          BGPDT,SIL,GE3S,GE4S,DYNS/S,N,DRY/*NAMESØLS*/S,N,LUSET/
          S,N,NØGPDT $
PURGE     CSTM $
EQUIV     GE3S,GEØM3/ALWAYS/GE4S,GEØM4/ALWAYS/CASEI,CASECC/ALWAYS
          DYNS,DYNAMICS/ALWAYS $
CØND      LBSTP,DRY $
ALTER     (Remove PLØT)
ALTER     (Remove NØSIMP PURGE and CØND)
ALTER     (Remove GPWG and SMA3)
SØFI      /KNØS,MNØS,BNØS,K4NØS,/DRY/*NAMESØLS*/*KMTX*/*MMTX*/*BMTX*/
          *K4MX* $
EQUIV     KNØS,KGG/NØKGGX $        }
CØND      LB2K,NØKGGX $            }
ADD       KGGX,KNØS/KGG $          }  (K only)
LABEL     LB2K $                   }
EQUIV     MNØS,MGG/NØMGG $         }
CØND      LB2M,NØMGG $             }
ADD       MGG,MNØS/MGGX $          }  (M only)
EQUIV     MGGX,MGG/ALWAYS $        }
LABEL     LB2M $                   }
EQUIV     BNØS,BGG/NØBGG $         }
CØND      LB2B,NØBGG $             }
ADD       BGG,BNØS/BGGX $          }  (B only)
EQUIV     BGGX,BGG/ALWAYS $        }
LABEL     LB2B $                   }
EQUIV     K4NOS,K4GG/NØK4GG $      }
CØND      LB2K4,NØK4GG $           }
ADD       K4GG,K4NØS/K4GGX $       }  (K4 only)
EQUIV     K4GGX,K4GG/ALWAYS $      }
LABEL     LB2K4 $                  }
LABEL     LBSTP $
CHKPNT    MGG,BGG,K4GG $
```

Raw DMAP, Rigid Formats 8, 9 (continued)

```
36   ALTER    (Remove MDEMA, KDEK2 PARAM)
37   PARAM    //*AND*/MDEMA/NØUE/NØM2PP $
38   PARAM    //*ADD*/KDEK2/1/0 $   (K only)
39   PARAM    //*ADD*/NØMGG/1/0 $   (M only)
40   PARAM    //*ADD*/NØBGG/1/0 $   (B only)
41   PARAM    //*ADD*/NØK4GG/1/0 $   (K4 only)
42   ALTER    (Remove NØSIMP, NØGPDT EQUIV)
43   EQUIV    K2DD,KDD/KDEK2 $
44   EQUIV    M2DD,MDD/NØMGG $
45   EQUIV    B2DD,BDD/NØBGG $
46   ALTER    (Remove SDR2 and PLØT)
47   EQUIV    UPVF,UPVC/NØA $
48   CØND     LBL19,NØA $
49   SDR1     USETD,,UDVF,,,GØD,GMD,,,,/UPVC,,/1/DYNAMICS $
50   LABEL    LBL19 $
51   CHKPNT   UPVC $
52   EQUIV    UPVC,UGV/NØUE $
53   CØND     LBUE,NØUE $
54   UPARTN   USET,UPVC/UGV,UEV,,/*P*/*G*/*E* $
55   LABEL    LBUE $
```

Variables:

NAMESØLS	= Name of solution structure
NØS	= Internal number of solution structure
STP	= Step number
UDVF	= UDVF for R.F. 8, UDVT for R.F. 9

DMAP for Command: SUBSTRUCTURE

The SUBSTRUCTURE command is necessary to initiate the automatic DMAP process. In Phase 1, the SUBPH1 module is used to build the substructure tables on the SØF from the NASTRAN grid point tables and the SØFØ module is used to copy the matrices onto the SØF. In Phase 2 and Phase 3, the initial value of the DRY parameter is set and the DMAP sequence is initiated.

Raw DMAP:

PHASE 1

```
ALTER      2,0
PARAM      //*NØP*/ALWAYS=-1 $
SGEN       CASECC,,,/CASESS,CASEI,,,,,,,,/S,N,DRY/*XXXXXXXX*/S,N,LUSET/
           S,N,NØGPDT $
EQUIV      CASEI,CASECC/ALWAYS $
ALTER      (After GP4)
PARAM      //*ADD*/DRY-1 /0 $
LABEL      LBSBEG $
CØND       LBLIS,DRY $   (R.F. 1, 2, 3, and 9 only)
SSG1       SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,CASECC,DIT/PG/   }
           LUSET/NSKIP $                                             } (R.F. 9 and P
CHKPNT     PG $                                                      }  or PA only)
ALTER      (Remove DECØMP)
SSG2       USET,GM,,KFS,GO,,PG/QR,PØ,PS,PL $                         } (R.F. 9 and P
CHKPNT     PØ,PS,PL $                                                }  or PA only)
LABEL      LBLIS $   (R.F. 1, 2, 3, and 9 only)
ALTER      (Remove solution)
SUBPH1     CASECC,EQEXIN,USET,BGPDT,CSTM,GPSETS,ELSETS//S,N,DRY/
           *NAME    */PLØTID /*PVEC* $
CØND       LBSEND,DRY $
EQUIV      PG,PL/NØSET $
CØND       LBL10,NØSET $                                             } (R.F. 1, 2, or
SSG2       USET,GM,YS,KFS,GØ,,PG/QR,PØ,PS,PL $                       }  3 and P or PA
CHKPNT     PØ,PS,PL $                                                }  only)
LABEL      LBL10 R                                                   }
SØFØ       ,KAA,MAA,PL,BAA,K4AA//S,N,DRY/*NAME*/*KMTX*/*MMTX*/PVEC*/
           *BMTX*/*K4MX* $
LØDAPP     PL,//*NAME    */S,N,DRY $   (R.F. 1, 2, 3, or 9 and PA only)
EQUIV      CASESS,CASECC/ALWAYS $
```

AUTOMATIC SUBSTRUCTURE DMAP ALTERS

PHASE 2

1	ALTER	2,0
2	PARAM	//*ADD*/DRY/I/0 $
3	LABEL	LBSBEG $

PHASE 3

1	ALTER	(Remove DECØMP or before dynamic solution)
2	PARAM	//*ADD*/DRY/I/0 $
3	LABEL	LBSBEG $

Variables:

I	= Integer RUN option code (see RUN command)
NAME	= Phase 1 substructure name
PLØTID	= Phase 1 Plot Set ID
KAA,MAA,PL, BAA,K4AA	= Data blocks dependent on ØPTIØN
PVEC	= PVEC for option P, PAPP for option PA

5.10 SUPPLEMENTARY FUNCTIONAL MODULES

These modules are fully described in Section 4 of the Programmer's Manual. However, since they are not incorporated in any of the Rigid Formats, they are included here for reference purposes. These modules must be ALTERed into Rigid Formats.

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DIRECT MATRIX ABSTRACTION

I. NAME: EMA1 (Element Matrix Assembler)

II. PURPOSE: This module superimposes matrices corresponding to elements into a structural matrix corresponding to all degrees of freedom at all grid points.

III. DMAP CALLING SEQUENCE:

$$\text{EMA1}\quad \text{GPECT},\left\{\begin{matrix}\text{KDICT}\\ \text{MDICT}\end{matrix}\right\},\left\{\begin{matrix}\text{KELM}\\ \text{MELM}\end{matrix}\right\},\text{SIL,ECT/}\left\{\begin{matrix}\text{KGGX}\\ \text{MGG}\end{matrix}\right\},\ \text{GPST/C,N,NØK4/C,N,WTMASS}\quad \$$$

IV. INPUT DATA BLOCKS:

GPECT - Grid Point Element Connection Table

$\left.\begin{matrix}\text{KDICT}\\ \text{MDICT}\end{matrix}\right\}$ - Element Matrix Dictionaries

$\left.\begin{matrix}\text{KELM}\\ \text{MELM}\end{matrix}\right\}$ - Element Matrix Partitions

SIL - Scalar Index List

ECT - Element Connection Table

V OUTPUT DATA BLOCKS:

KGGX - Assembled Structural Matrix

MGG - Assembled Mass Matrix

GPST - Grid Point Singularity Table

Note: GPST may be purged.

VI. PARAMETERS:

NØK4 - Input, integer, default = -1. Flag which specifies whether damping factor is to be used in assembling matrix (-1 ignores factor).

WTMASS - Input, real, default = 1.0. Constant by which all element matrix terms are multiplied.

VII. EXAMPLE:

To replace the current module EMA with module EMA1 in Static Analysis (Rigid Format 1), the following ALTERs must be made:

```
ALTER n1,n1 $ STRUCTURAL MATRIX (where n1 = DMAP statement number of the EMA module
                                 corresponding to the stiffness matrix)
EMA1     GPECT,KDICT,KELM,SIL,ECT/KGGX,GPST $
ALTER n2,n2 $ MASS MATRIX (where n2 = DMAP statement number of the EMA module corresponding
                           to the mass matrix)
EMA1     GPECT,MDICT,MELM,SIL,ECT/MGG,/-1/C,Y,WTMASS=1.0 $
ENDALTER $
```

I. NAME: GPSPC (Constrain Stiffness Matrix Singularities)

II. PURPOSE: The GPST data block contains data on potential stiffness matrix singularities. These singularities may have been removed through the application of single or multipoint constraints. The GPSPC module checks each singularity against the list of constraints, and if the singularity is not thereby removed, writes a warning for the user and on user's option automatically constrains the singularity. This module will not be used if GENELs are present.

III. DMAP CALLING SEQUENCE:

```
GPSPC   GPL,GPST,USET,SIL / ØGPST,USETC / V,N,NØGPST / V,Y,SINCØN / V,N,SINGLE /
        V,N,ØMIT / V,N,REACT / V,N,NØSET / V,N,NØL / V,N,NØA $
```

IV. INPUT DATA BLOCKS:

GPL - Grid Point List

GPST - Grid Point Singularity Table

USET - Displacement Set Definitions Table

SIL - Scalar Index List

Note: No input data block can be purged.

V. OUTPUT DATA BLOCKS:

ØGPST - Tabular list cf grid point singularities not removed by user. This data block will be processed by the ØFP (Output File Processor) module.

USETC - Displacement Set Definition Table with singularities constrained.

VI. PARAMETERS:

NØGPST - Output, integer, default = 1. If positive, ØGPST was created.

SINCØN - Input-output, integer, default = -1. If SINCØN is negative on input, remaining singularities are automatically constrained. On output, same negative value if singularities existed, zero otherwise.

SINGLE, ØMIT, REACT, NØSET, NØL, NØA - Input-output, integer, no default. See description of GP4 parameters of the same name in Programmer's Manual Section 4.31. Values are corrected only if singularities were constrained.

VII. EXAMPLES:

1. To use the GPSPC module instead of the standard GPSP module in a static analysis (Rigid Format 1), module GPSP is replaced by module GPSPC and the USET data block is replaced by the USETC data block. In this case, the following ALTERs are required:

```
ALTER     n1,n2 $ (where n1 and n2 are the DMAP statement numbers of the PARAM and PURGE
          statements following the GP4 module)

ALTER     n3,n3 $ (where n3 = DMAP statement number of the GPSP module)

GPSPC     GPL,GPST,USET,SIL/ØGPST,USETC/S,N,NØGPST/S,Y,SINCØN=-1/
          S,N,SINGLE/S,N,ØMIT/S,N,REACT/S,N,NØSET/S,N,NØL/S,N,NØA $

EQUIV     USETC,USET/SINCØN $

ALTER     n4 $ (where n4 = DMAP statement number of the ØFP module immediately following
          the GPSP module)

PARAM     //*ADD*/SING/V,Y,SINCØN/1 $

CØND      ERRØR3,NØL $

CØND      ERRØR,SING $

ALTER     n5 $ (where n5 = DMAP statement number of LABEL LBL4)

PARAM     //*AND*/NØSR/SINGLE/REACT $

PURGE     KRR,KLR,QR,DM/REACT /GM/MPCF1 /GØ,KØØ,LØØ,PØ,UØØV,RUØV/ØMIT /
          PS,KFS,KSS/SINGLE /QG/NØSR $

LABEL     ERRØR $

PRTPARM   //0/*SINCØN* $

ENDALTER $
```

The input parameter SINCØN can be changed from the initial value illustrated for the general case, by either using the form C,N,i or by using a PARAM bulk data card with a different value. Note that when SINCØN = -1, the strongest combination of possible singularities is automatically constrained and noted in the GPST output.

2. To use the GPSPC module instead of the standard GPSP module in a real eigenvalue analysis (Rigid Format 3), module GPSP is replaced by module GPSPC and the USET data block is replaced by the USETC data block. In this case, the following ALTERs are required:

```
ALTER     n1,n1 $ (where n1 = DMAP statement number of the PURGE module following the GP4
          module)

ALTER     n2,n2 $ (where n2 = DMAP statement number of the GPSP module)

GPSPC     GPL,GPST,USET,SIL/ØGPST,USETC/S,N,NØGPST/S,Y,SINCØN=-1/
          S,N,SINGLE/S,N,ØMIT/S,N,REACT/S,N,NØSET/S,N,NØL/S,N,NØA $

CØND      ERRØR3,NØL $

EQUIV     USETC,USET/SINCØN $

ALTER     n3 $ (where n3 = DMAP statement number of LABEL LBL4)

PARAM     //*ADD*/SING/V,Y,SINCØN/1 $
```

```
CØND      ERRØR,SING $

PURGE     KRR,KLR,DM,MLR,MR/REACT /GM/MPCF1 /GØ/ØMIT /KFS/SINGLE /
          QG/NØSET $

LABEL     ERRØR $

PRTPARM   //0/*SINCØN* $

ENDALTER $
```

The input parameter SINCØN can be changed from the initial value illustrated for the general case, by either using the form C,N,i or by using a PARAM bulk data card with a different value. Note that when SINCØN = -1, the strongest combination of possible singularities is automatically constrained and noted in the GPST output.

6. DIAGNOSTIC MESSAGES

6.1 NASTRAN MESSAGES

There are three categories of diagnostic messages in NASTRAN. They are:

1. Rigid format error messages
2. Structure plotter error messages
3. NASTRAN system and user diagnostic messages

The rigid format error messages are fully described in Section 3 under the description of the individual rigid formats. The structure plotter error messages are described in Section 4.2.3. The NASTRAN system and user diagnostic messages are detailed in this section.

The system and user diagnostic messages issued by NASTRAN are identified by numbers. Message numbers have been assigned in groups as follows:

1 - 1000	Preface Messages
1001 - 2000	Executive Module Messages
2001 -	Functional Module Messages

These messages have the following format:

$$*** \begin{Bmatrix} \text{SYSTEM} \\ \text{USER} \end{Bmatrix} \begin{Bmatrix} \text{FATAL} \\ \text{WARNING} \\ \text{INFØRMATION} \end{Bmatrix} \text{ MESSAGE id, text.}$$

where "id" is a unique message identification number and "text" is the message as indicated in capital letters for each of the diagnostic messages. A series of asterisks (****) in the text indicates information that will be filled in for a specific use of the message, such as the number of a grid point or the name of a bulk data card. Many of the messages are followed by additional explanatory material, including suggestions for remedial action.

The system and user messages described in this section pertain only to those messages generated by NASTRAN. Although these messages can appear at various places in the output stream, they should be easily identified by their format. The various computer operating systems also produce diagnostic messages that can appear at various places in the output stream. The format of these messages will vary with the operating system. Reference should be made to the operating system manuals for interpretation of the messages that are not generated by NASTRAN.

System messages refer to diagnostics that are associated with program errors. In general, such errors cannot be corrected by the user. Reference should be made to the Programmer's Manual

and assistance secured from the programming staff. User messages refer to errors that are usually associated with the preparation of the NASTRAN Data Deck. Corrective action is indicated in the message text or the explanatory information following the text. In some cases reference may have to be made to other sections of the User's Manual for proper card formats or for clarification of procedures.

Fatal messages cause the termination of the execution following the printing of the message text. These messages will always appear at the end of the NASTRAN output. Warning and information messages will appear at various places in the output stream. Such messages only convey warnings or information to the user. Consequently, the execution continues in a normal manner following the printing of the message text.

As an example, consider message number 2025, which will appear in the printed output as follows:

*** USER FATAL MESSAGE 2025, UNDEFINED CØØRDINATE SYSTEM 102.

The three leading asterisks (***) are always present in the system and user diagnostic messages. The word USER indicates that this is a user message rather than a system message. The word FATAL indicates that this is a fatal message rather than a warning or an information message. The number 2025 is the identification number for this message. The text of the message follows the comma (,). The number 102 replaces the asterisks (****) in the general message text, and indicates that 102 is the identification number of the undefined coordinate system.

6.2 PREFACE MESSAGES

1 *** USER WARNING MESSAGE 1, PØSSIBLE ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, ASSUMED FIRST INPUT FILE IS NULL.

User has specified N input data blocks when there should be N+1.

2 *** USER WARNING MESSAGE 2, PØSSIBLE ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, PARAMETER NAMED ******** IS DUPLICATED.

No harm done. Parameter is saved just once.

3 *** USER FATAL MESSAGE 3, ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, FØRMAT ERRØR IN PARAMETER NØ. ***.

Double delimiter appears in parameter section of previous DMAP instruction.

4 *** SYSTEM FATAL MESSAGE 4, MPL PARAMETER ERRØR, MØDULE NAME = ******** PARAMETER NØ. ***.

MPL entry for module is incorrect. See subroutine XMPLDD.

5 *** USER FATAL MESSAGE 5, PARAMETER INPUT DATA ERRØR, ILLEGAL VALUE FØR PARAMETER NAMED ********.

The type of the parameter on a PARAM card is inconsistent with the type of the parameter by the same name in the above DMAP instruction.

6 *** USER FATAL MESSAGE 6, ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, ILLEGAL TYPE FØR PARAMETER NØ. ***.

The type of the parameter in the DMAP instruction does not correspond to type requested in DMD or MFD section of the Programmer's Manual.

7 *** USER FATAL MESSAGE 7, ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, PARAMETER NØ. *** NEEDS PARAMETER NAME.

Parameter is not in correct format.

8 *** USER FATAL MESSAGE 8, BULK DATA PARAM CARD ERRØR. MUST NØT DEFINE PARAMETER NAMED ********.

The "N" in V,N,******** means that the user cannot set the value of the parameter with the name ******** on a PARAM card.

9 *** USER FATAL MESSAGE 9, ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, VALUE NEEDED FØR PARAMETER NØ. ***.

Constant needs value in DMAP instruction or on a PARAM card.

10 *** USER PØTENTIALLY FATAL MESSAGE 10, PØSSIBLE ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, DEFAULT ØPTIØN FØR INPUT DATA BLØCKS. MAKE SURE MISSING BLØCKS ARE NØT REQUIRED.

11 *** USER PØTENTIALLY FATAL MESSAGE 11, PØSSIBLE ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, DEFAULT ØPTIØN FØR ØUTPUT DATA BLØCKS. MAKE SURE MISSING BLØCKS ARE NØT REQUIRED.

12 *** USER FATAL MESSAGE 12, ERRØR IN DMAP INSTRUCTIØN NØ. ****, ILLEGAL CHARACTER IN DMAP INSTRUCTIØN NAME.

Name must be 8 or fewer alpha-numeric characters, the first character being alpha.

13 *** USER FATAL MESSAGE 13, DMAP INSTRUCTIØN NØT IN MØDULE LIBRARY.

14 *** SYSTEM FATAL MESSAGE 14, ARRAY NAMED ******** ØVERFLØWED [AT DMAP INSTRUCTIØN NØ. ****].

See XGPI module description in the MFD section of the Programmer's Manual.

15 *** USER FATAL MESSAGE 15, ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, INCØNSISTENT TYPE USED FØR PARAMETER NAMED ********.

This parameter was used in a previous DMAP instruction which gave it a different type. See Section 5.2.1.

16 *** USER FATAL MESSAGE 16, ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, ILLEGAL FØRMAT.

17 *** USER FATAL MESSAGE 17, ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, UNIDENTIFIED NASTRAN CARD KEYWØRD ********. ACCEPTABLE KEYWØRDS FØLLØW ---

18 *** USER FATAL MESSAGE 18, ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, TØØ MANY PARAMETERS IN DMAP PARAMETER LIST.

Incorrect calling sequence for DMAP instruction.

19 *** USER FATAL MESSAGE 19, LABEL NAMED ******** IS MULTIPLY DEFINED.

LABEL named appears in more than one place in the DMAP program.

20 *** USER FATAL MESSAGE 20, ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, ILLEGAL CHARACTERS IN PARAMETER NØ. ***.

Name must be 8 or fewer alpha-numeric characters, the first character being alpha.

21 *** USER FATAL MESSAGE 21, ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, PARAMETER NAMED ******** IS NØT IN PRECEDING DMAP INSTRUCTIØN PARAMETER LIST.

Parameters in a SAVE instruction must appear in the immediately preceding DMAP instruction.

22 *** USER PØTENTIALLY FATAL MESSAGE 22, PØSSIBLE ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, DATA BLØCK NAMED ******** APPEARS AS INPUT BEFØRE BEING DEFINED.

See Section 5.2.

23 *** USER FATAL MESSAGE 23, ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, DATA BLØCK NAMED ******** IS NØT REFERENCED IN SUBSEQUENT FUNCTIØNAL MØDULE.

See Section 5.2. Error can be suppressed by adding the following:

```
PARAM    //*NØP*/TRUE=-1 $
CØND     LABELXXX,TRUE $
TABPT    ********,,,,// $
LABEL    LABELXXX $
```

24 *** SYSTEM FATAL MESSAGE 24, CANNØT FIND FILE NAMED ******** ØN DATA PØØL TAPE.

The contents of /XDPL/ do not match the contents of the Pool Tape.

25 *** USER FATAL MESSAGE 25, ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, PARAMETER NAMED ******** NØT DEFINED.

Parameter is referenced in a functional module, but is nowhere defined.

26 *** USER FATAL MESSAGE 26, ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, LABEL NAMED ******** NØT DEFINED.

LABEL name does not appear in LABEL instruction.

27 *** USER WARNING MESSAGE 27, LABEL NAMED ******** NØT REFERENCED.

LABEL name appears only in a LABEL instruction.

28 *** SYSTEM FATAL MESSAGE 28, UNEXPECTED END ØF TAPE ØN NEW PRØBLEM TAPE.

Either an EØT was truly encountered or file linkage has been destroyed in /XFIST/, /XPFIST/ and/or /XXFIAT/. This message will also appear when tape files on the NASTRAN Card have been declared disk files but insufficient space has been allocated for this purpose.

29 *** SYSTEM FATAL MESSAGE 29, UNEXPECTED END ØF TAPE ØN ØLD PRØBLEM TAPE.

See Message 28.

30 *** SYSTEM FATAL MESSAGE 30, UNEXPECTED END ØF TAPE ØN DATA PØØL TAPE.

See Message 28.

31 *** SYSTEM FATAL MESSAGE 31, CØNTRØL FILE ******** INCØMPLETE ØR MISSING ØN NEW PRØBLEM TAPE.

Data block XCSA is not in correct format or it is missing.

32 *** USER FATAL MESSAGE 32, ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, FILE NAMED ******** MUST BE DEFINED PRIØR TØ THIS INSTRUCTIØN.

See Section 5.2.

33 *** SYSTEM FATAL MESSAGE 33, NAME (********) IN NEW CØNTRØL FILE DICTIØNARY NØT VALID.

The first record of data block XCSA on Problem Tape contains a name which is not recognized by XGPI module.

34 *** SYSTEM FATAL MESSAGE 34, CANNØT TRANSLATE DMAP INSTRUCTIØN NØ. ****.

Refer to Section 5 of the User's Manual or Section 4 of the Programmer's Manual for the correct format of the instruction.

35 *** USER FATAL MESSAGE 35, INCØRRECT ØLD PRØBLEM TAPE MØUNTED. ID ØF TAPE MØUNTED = ********,********,**/**/** REEL =***. ID ØF TAPE DESIRED = ********,********,**/**/** REEL =***.

Wrong reel mounted for multireel Problem Tape.

36 *** SYSTEM FATAL MESSAGE 36, CANNØT FIND FILE NAMED ******** ØN ØLD PRØBLEM TAPE.

The header record of the file on Problem Tape does not match the file name in restart dictionary.

37 *** USER WARNING MESSAGE 37, PØSSIBLE ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, WARNING ØNLY - MAY NØT BE ENØUGH FILES AVAILABLE FØR MØDULE REQUIREMENTS. FILES NEEDED = *** FILES AVAILABLE = ***.

Program will execute if enough data blocks referenced by the module are purged. Purged data blocks are not assigned files.

38 *** SYSTEM FATAL MESSAGE 38, NØT ENØUGH CØRE FØR GPI TABLES.

Increase Region Size, Field Length, HICØRE allocation or the length of the open core CØMMØN block, depending on the machine being used.

39 *** SYSTEM FATAL MESSAGE 39, RIGID FØRMAT DMAP SEQUENCE DØES NØT CØRRESPØND TØ MED TABLE.

The MED Table must have the same number of entries as there are DMAP instructions in the DMAP sequence.

40 *** USER FATAL MESSAGE 40, ERRØR IN ALTER DECK - CANNØT FIND END ØF DMAP INSTRUCTIØN.

User should check the ALTER part of the Executive Control Deck.

41 *** SYSTEM FATAL MESSAGE 41, TABLES INCØRRECT FØR REGENERATING DATA BLØCK ********.

File Name Table and MED Table used by routine XFLDEF are wrong.

42 *** USER WARNING MESSAGE 42, PØSSIBLE ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, PARAMETER NAMED ******** ALREADY HAD VALUE ASSIGNED PREVIØUSLY.

Parameter appears in a previous instruction which assigned it a value. The previous value will be used.

43 *** USER FATAL MESSAGE 43, INCØRRECT FØRMAT FØR NASTRAN CARD.

44 *** USER FATAL MESSAGE 44, ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, UNABLE TØ FIND END DMAP INSTRUCTIØN.

User has ALTERed out the END instruction.

45 *** USER PØTENTIALLY FATAL MESSAGE 45, PØSSIBLE ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, DATA BLØCK NAMED ******** ALREADY APPEARED AS ØUTPUT.

See Section 5.2.

46 *** USER FATAL MESSAGE 46, INCØRRECT REENTRY PØINT.

The last reentry card in the restart dictionary has a DMAP instruction number greater than the instruction number on the END card of the DMAP program.

47 *** USER FATAL MESSAGE 47, ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, THIS INSTRUCTIØN CANNØT BE FIRST INSTRUCTIØN ØF LØØP.

CHKPNT DMAP instruction must not follow a LABEL instruction which is located at the top of a loop.

48 *** USER WARNING MESSAGE 48, PØSSIBLE ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, DATA BLØCK ******** IS ALWAYS REGENERATED, THEREFØRE IT WILL NØT BE CHECKPØINTED.

This data block is generated by the Input File Processor (IFP) and must not be checkpointed to insure proper restart.

49 *** SYSTEM FATAL MESSAGE 49, MPL TABLE (MØDULE PRØPERTIES LIST) IS INCØRRECT.

Error is in CØMMØN block /XGP12/.

51 *** SYSTEM FATAL MESSAGE 51, NØT ENØUGH ØPEN CØRE FØR XGPIBS RØUTINE.

Additional core memory is required.

52 *** SYSTEM FATAL MESSAGE 52, NAMED CØMMØN /XLINK/ IS TØØ SMALL.

There must be one word in LINK table for every entry in MPL.

53 *** USER FATAL MESSAGE 53, INCØRRECT FØRMAT IN ABØVE CARD.

54 (1) *** USER WARNING MESSAGE 54, PARAMETER NAMED **** NØT REFERENCED.

54 (2) *** SYSTEM WARNING MESSAGE 54, THE NUMBER ØF MØDULES SPECIFIED IN THE LINK SPECIFICATIØN TABLE, **** EXCEEDS THE ALLØWABLE NUMBER SPECIFIED BY SEMDBD, ****.

The parameter LXLINK in CØMMØN /XLINK/ was exceeded when a new module was added to the program.

55 *** USER FATAL MESSAGE 55, PRECHK NAME LIST EXCEEDS MAXIMUM LIMIT (50).

56 *** USER WARNING MESSAGE 56, ILLEGAL ØPTIØN ØN XDMAP CARD - IGNØRED.

57 *** USER FATAL MESSAGE 57, VARIABLE REPT PARAMETER MUST BE AN INTEGER.

58 *** USER FATAL MESSAGE 58, VARIABLE REPT PARAMETER MUST BE DEFINED PRIØR TØ INSTRUCTIØN.

59 *** USER WARNING MESSAGE 59, PØØL FILE ERRØR - DMAP CRØSS-REF TERMINATED.

60 *** USER PØTENTIALLY FATAL MESSAGE 60, INSUFFICIENT ØPEN CØRE FØR DMAP CRØSS-REF - TERMINATED.

61 *** USER FATAL MESSAGE 61, ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, SAVE INSTRUCTIØN ØUT ØF SEQUENCE.

62 *** USER FATAL MESSAGE 62, ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, INCØRRECT NUMBER ØF INPUT DATA BLØCKS ENCØUNTERED.

63 *** USER FATAL MESSAGE 63, ERRØR IN DMAP INSTRUCTIØN ****, INSTRUCTIØN NØ. ****, INCØRRECT NUMBER ØF ØUTPUT DATA BLØCKS ENCØUNTERED.

64 *** USER WARNING MESSAGE 64, **** IS NØT DEFINED AS A NASTRAN FILE AND WILL BE IGNØRED.

65 *** SYSTEM FATAL MESSAGE 65, PØINTER ** = **** DØES NØT AGREE WITH LMPL = ****.

An error has been made in counting the number of MPL array entries for a particular module or the LMPL value has not been updated. Recheck any recent changes to the XMPLDD subroutine.

66 *** SYSTEM FATAL MESSAGE 66, ILLEGAL PARAMETER TYPE CØDE.

The parameter type code in an MPL table entry must be an integer between 1 and 6. See Section 2.4.2.2 of the Programmer's Manual.

67 *** SYSTEM FATAL MESSAGE 67, ERRØR IN PARAMETER SEQUENCE.

A format error exists in an MPL table entry for a particular module. See Section 2.4.2.2 of the Programmer's Manual.

68 *** SYSTEM FATAL MESSAGE 68, ILLEGAL WØRD CØUNT.

The number of words in an MPL table entry for a particular module must be a positive integer.

201 *** USER FATAL MESSAGE 201, REQUESTED BULK DATA DECK ********, NØT ØN USER MASTER FILE.

Requested UMF problem identification number not found on currently mounted UMF tape.

202 *** SYSTEM FATAL MESSAGE 202, UMF CØULD NØT BE ØPENED.

User's Master File (UMF) not present (destroyed) in FIST.

203 *** SYSTEM FATAL MESSAGE 203, ILLEGAL EØR ØN UMF.

User's Master File (UMF) contains no records in requested file.

204 *** USER FATAL MESSAGE 204, CØLD START, NØ BULK DATA.

No data cards were found after the BEGIN BULK card. A blank card will satisfy this rule.

205 *** USER WARNING MESSAGE 205, CØLD START, DELETE CARDS IGNØRED.

Delete (/) cards were present within the Bulk Data Deck and were ignored.

206 *** USER FATAL MESSAGE 206, PREVIØUS ******** CØNTINUATIØN CARDS, THØUGH VALID, CANNØT BE PRØCESSED BECAUSE ØF ERRØRS ØN ØTHER RELATED CØNTINUATIØN CARDS.

207 *** USER INFØRMATIØN MESSAGE 207, BULK DATA NØT SØRTED, XSØRT WILL REØRDER DECK.

The Bulk Data Deck was not in alpha-numeric sort. Sorting will be performed. Sorting of a large deck can be time consuming.

208 *** USER FATAL MESSAGE 208, PREVIØUS CARD IS A DUPLICATE PARENT.

Two or more cards were found with columns 74-80 identical and a continuation card is present with that mnemonic (columns 2-8).

209 *** USER FATAL MESSAGE 209, PREVIØUS ******** CØNTINUATIØN MNEMØNICS HAVE NØ PARENTS AND/ØR ARE DUPLICATES.

This message results due to either or both of the following reasons: (a) one or more cards with continuation mnemonics in columns 2 through 8 could not be matched with any other card continuation mnemonic in columns 73 through 80 or (b) two or more cards with continuation mnemonics in columns 2 through 8 were identical.

210 *** SYSTEM FATAL MESSAGE 210, SCRATCH CØULD NØT BE ØPENED.

One of the required scratch files was not present (destroyed) in FIST.

211 *** SYSTEM FATAL MESSAGE 211, ILLEGAL EØR ØN SCRATCH.

A required scratch file was formatted improperly.

212 *** SYSTEM FATAL MESSAGE 212, ILLEGAL EØF ØN ITAPE4.

Scratch file containing continuations was mispositioned.

213 *** SYSTEM FATAL MESSAGE 213, ILLEGAL EØF ØN ØPTP.

Old Problem Tape contained no bulk data (illegal format).

214 *** SYSTEM FATAL MESSAGE 214, ØPTP CØULD NØT BE ØPENED.

Old Problem Tape (ØPTP) not present (destroyed) in FIST.

215 *** SYSTEM FATAL MESSAGE 215, NPTP CØLD NØT BE ØPENED.

New Problem Tape (NPTP) not present (destroyed) in FIST.

216 *** SYSTEM FATAL MESSAGE 216, ILLEGAL INDEX.

FØRTRAN computed-GØ-TØ has received an illogical value.

217 *** SYSTEM FATAL MESSAGE 217, ILLEGAL EØF ØN ITAPE4.

218 *** USER FATAL MESSAGE 218, ILLEGAL VALUE ØR FØRMAT SPECIFIED IN PARM FIELD.

The core statistics request or the number of bytes to free back to the operating system has not been defined properly on the EXEC statement card. (IBM only.)

219 *** USER FATAL MESSAGE 219, MISSING ENDDATA CARD.

220 *** USER FATAL MESSAGE 220, MISSING ENDDATA CARD.

221 *** USER FATAL MESSAGE 221, EXTRANEØUS DATA IN FIELD 1 ØF BULK DATA DELETE CARD.

300 (1) *** USER FATAL MESSAGE 300, DATA ERRØR IN FIELD UNDERLINED.

A data error as described in the text has been detected by utility routine XRCARD or RCARD.

300 (2) *** USER FATAL MESSAGE 300, INVALID DATA CØLUMN 72.

Error in format of exponent.

300 (3) *** USER FATAL MESSAGE 300, INTEGER DATA ØUT ØF MACHINE RANGE.

The limits are $2^{31}-1$ for IBM, $2^{59}-1$ for CDC, $2^{35}-1$ for UNIVAC and $2^{31}-1$ FØR VAX.

300 (4) *** USER FATAL MESSAGE 300, INVALID CHARACTER FØLLØWING INTEGER IN CØLUMN ***.

Either an illegal delimiter was detected or a real number is missing the decimal.

300 (5) *** USER FATAL MESSAGE 300, DATA ERRØR - UNANTICIPATED CHARACTER IN CØLUMN ***.

A $\pm$ E or $\pm$ D was expected based on other input data.

300 (6) *** USER FATAL MESSAGE 300, DATA ERRØR MISSING DELIMITER ØR REAL PØWER ØUT ØF MACHINE RANGE.

Either no delimiter was found or the power was exceeded. The limits are E-78 to E+75 for IBM, E-38 to E+38 for UNIVAC, E-294 to E+322 for CDC and E-38 to E+38 for VAX.

300 (7) *** USER FATAL MESSAGE 300, RØUTINE XRCARD FINDS ØUTPUT BUFFER TØØ SMALL TØ PRØCESS CARD CØMPLETELY.

301 *** USER WARNING MESSAGE 301, BULK DATA CARD ******* CØNTAINS INCØNSISTENT DATA. SØRTED CARD CØUNT = ******.

302 *** USER WARNING MESSAGE 302, ØNE ØR MØRE GRID CARDS HAVE DISPLACEMENT CØØRDINATE SYSTEM ID ØF -1.

303 *** SYSTEM FATAL MESSAGE 303, no open core for IFP.

Overlay structure must be redefined.

304 *** SYSTEM FATAL MESSAGE 304, IFP NØT READING NPTP. FILE BEING READ = ****.

The Input File Processor subroutine IFP attempts to locate the bulk data file on the NPTP by searching it forward. The first two words of the file header records are examined for a match with the Hollerith string BULKDATA. If the bulk data is not found by the fifth file, the assumption is made that IFP is either not reading NPTP or that it has been badly written. The header record of the fifth file is printed as part of the message.

305 *** SYSTEM FATAL MESSAGE 305, GINØ CANNØT ØPEN FILE ******.

Unexpected nonstandard return from ØPEN.

306 *** SYSTEM FATAL MESSAGE 306, READ LØGIC RECØRD ERRØR.

Short record encountered. Bulk data card images occupy 20 words.

307 *** USER FATAL MESSAGE 307, ILLEGAL NAME FØR BULK DATA CARD ******.

See Section 2.4.

308 *** USER FATAL MESSAGE 308, CARD ****** NØT ALLØWED IN ****** APPRØACH.

See Section 2.4.

309 *** USER WARNING MESSAGE 309, CARD ****** IMPRØPER IN ******** APPRØACH.

See Section 2.4.

310 *** USER FATAL MESSAGE 310, CARD ****** NØT ALLØWED IN SAME DECK AS AXIC CARD.

See Section 2.4.

311 *** USER FATAL MESSAGE 311, NØNUNIQUE FIELD 2 ØN BULK DATA CARD **** ****. SØRTED CARD CØUNT = ****.

The sorted bulk data card indicated must have a unique integer in field 2.

312 *** USER FATAL MESSAGE 312, TØØ MANY CØNTINUATIØNS FØR BULK DATA CARD **** ****. SØRTED CARD CØUNT = ****.

See bulk data card description in Section 2.4.

313 *** USER FATAL MESSAGE 313, ILLEGAL NUMBER ØF WØRDS ØN BULK DATA CARD **** ****. SØRTED CARD CØUNT = ****.

See bulk data card description in Section 2.4.

314 *** SYSTEM FATAL MESSAGE 314, INVALID CALL FRØM IFP. K = ****.

Code error, machine failure, or cell is being destroyed.

315 *** USER FATAL MESSAGE 315, FØRMAT ERRØR ØN BULK DATA CARD **** ****. SØRTED CARD CØUNT = ****.

See bulk data card description in Section 2.4.

316 *** USER FATAL MESSAGE 316, ILLEGAL DATA ØN BULK DATA CARD **** ****. SØRTED CARD CØUNT = ****.

See bulk data card description in Section 2.4.

317 *** USER FATAL MESSAGE 317, BAD DATA ØR FØRMAT ØR NØNUNIQUE NAME DTI **** SØRTED CARD CØUNT ****.

See bulk data card description in Section 2.4.

318 *** SYSTEM FATAL MESSAGE 318, NØ RØØM IN /XDPL/ FØR DTI ****.

Overflow of the Data Pool Table. See Section 2 of the Programmer's Manual.

319 *** SYSTEM FATAL MESSAGE 319, IFP READING EØF ØN NPTP.

Unexpected EØF encountered while attempting to read a card image.

320 *** USER FATAL MESSAGE 320, IFP ERRØR ****** LAST CARD PRØCESSED IS ******. SØRTED CARD CØUNT = ****.

Code error in IFP or XSØRT.

321 *** USER FATAL MESSAGE 321, NØNUNIQUE PARAM NAME *****.

The names of all parameters must be unique.

322 *** SYSTEM FATAL MESSAGE 322, ILLEGAL ENTRY TØ IFSiP.

IFP code error detected in IFS1P, IFS2P, IFS3P, IFS4P or IFS5P.

324 *** USER WARNING MESSAGE 324, BLANK CARD(S) IGNØRED.

Blank bulk data cards are ignored by NASTRAN.

325 *** USER FATAL MESSAGE 325, BAD DATA ØR FØRMAT ØR NØNUNIQUE NAME. DMI ****** SØRTED CARD CØUNT = ****.

See bulk data card description in Section 2.4.

326 *** SYSTEM FATAL MESSAGE 326, NØ RØØM IN /XDPL/ FØR DMI ******.

Overflow of the Data Pool Table. See Section 2 of the Programmer's Manual.

327 *** USER FATAL MESSAGE 327, BAD DATA ØR FØRMAT ØR NØNUNIQUE NAME. DMIG ****** SØRTED CARD CØUNT = ****.

See bulk data card description in Section 2.4.

329 *** USER FATAL MESSAGE 329, ØNLY ØNE (1) AXIC CARD ALLØWED.

See bulk data card description in Section 2.4.

330 *** SYSTEM FATAL MESSAGE 330, NØ RØØM IN CØRE FØR PARAM CARDS.

Change overlay or increase core size.

331 *** USER FATAL MESSAGE 331, IMPRØPER PARAM CARD ******, SØRTED CARD CØUNT = ****.

See bulk data card description in Section 2.4.

332 *** USER FATAL MESSAGE 332, AXIC CARD REQUIRED.

The presence of any conical shell data cards requires the presence of an AXIC card. See the AXIC bulk data card description in Section 2.4.

333 *** USER FATAL MESSAGE 333, UNABLE TØ SØRT ******** MULTI-ENTRY CARD DATA IN SUBRØUTINE IFP DUE TØ INSUFFICIENT CØRE. ADDITIØNAL CØRE REQUIRED = ********** WØRDS.

Either increase the core or manually sort multi-entry data cards (CRØD, PTRMEM, etc.).

334 *** USER INFØRMATIØN MESSAGE 334, ******** MULTI-ENTRY CARD DATA ARE NØT SØRTED ØN THEIR {ELEMENT / PRØPERTY} IDS. SUBRØUTINE IFP WILL SØRT THE DATA.

335 *** USER FATAL MESSAGE 335, NØNUNIQUE {ELEMENT / PRØPERTY} ID ******** ENCØUNTERED IN ******** MULTI-ENTRY CARD DATA.

Element and property identification numbers in multi-entry bulk data cards (CRØD, PTRMEM, etc.) must be unique integers.

336 *** USER FATAL MESSAGE 336, RFØRCE DATA IN SET NØ. ******** CØNTAINS ILLEGAL DIRECTIØN FØR AXISYMMETRIC PRØBLEM.

Only the z component of the rotation direction vector can be defined. See the RFØRCE data card description for details.

337 *** USER FATAL MESSAGE 337, BØTH AXIC AND AXIF CARDS USED IN BULK DATA.

Axisymmetric structural problems and hydroelastic problems are entirely different and AXIC and AXIF cards are mutually exclusive in the Bulk Data Deck.

338 *** USER FATAL MESSAGE 338, AXISYMMETRIC CARD REQUIRED IN CASE CØNTRØL DECK.

An AXIC or AXIF card was found in the Bulk Data Deck but the required AXISYMMETRIC card was omitted from the Case Control Deck.

339 *** USER FATAL MESSAGE 339, ILLEGAL USE ØF AXISYMMETRIC CARD IN CASE CØNTRØL DECK.

An AXISYMMETRIC card was used in Case Control Deck but neither an AXIC nor an AXIF card was present in the Bulk Data Deck.

340 *** USER FATAL MESSAGE 340, PARAM CARDS REQUIRED BY $\left\{\begin{matrix}\text{DISP}\\\text{AERØ}\end{matrix}\right\}$ RIGID FØRMAT **** NØT FØUND IN BULK DATA.

Refer to Section 3 for the PARAM card parameters required by the rigid format indicated.

341 *** USER FATAL MESSAGE 341, LMØDES ØR HFREQ/LFREQ PARAM REQUIRED BY $\left\{\begin{matrix}\text{DISP}\\\text{AERØ}\end{matrix}\right\}$ RIGID FØRMAT **** NØT IN BULK DATA ØR TURNED ØFF.

The modal frequency range or the number of modes required for a modal analysis problem was incorrectly specified.

342 *** USER FATAL MESSAGE 342, LMØDES PARAM FØUND IN BULK DATA WITH HFREQ ØR LFREQ.

Only one or the other of the two methods must be used to specify the range of modes to be used in a modal analysis problem.

343 *** USER FATAL MESSAGE 343, NØDJE PARAM SPECIFIED FØR AERØ RIGID FØRMAT **** BUT P1, P2, ØR P3 ØMITTED.

A tape operation parameter required by the INPUTT2 module was missing.

344 *** USER WARNING MESSAGE 344, P1, P2, ØR P3 PARAM FØUND IN BULK DATA BUT NØDJE MISSING ØR TURNED ØFF.

345 *** USER FATAL MESSAGE 345, CTYPE ØR NSEGS PARAM REQUIRED BY DISPLACEMENT RIGID FØRMAT **** MISSING ØR INCØRRECT.

346 *** USER FATAL MESSAGE 346, KINDEX PARAM REQUIRED BY DISPLACEMENT RIGID FØRMAT 15 MISSING ØR TURNED ØFF.

The harmonic index must be specified for problems involving normal modes with cyclic symmetry.

347 *** USER FATAL MESSAGE 347, DYNAMIC PRESSURE (Q) PARAM REQUIRED BY AERØ RIGID FØRMAT 11 NØT IN BULK DATA.

348 *** USER FATAL MESSAGE 348, FIRST CHARACTER ØN CARD IS NUMERIC. INCØRRECT FØRMAT ØR INCØRRECT CØNTINUATIØN ØN PREVIØUS CARD.

Check card above message or preceding one for format errors.

349 *** USER FATAL MESSAGE 349, PLØT CØMMAND **** NØT RECØGNIZED. CHECK SPELLING AND FØRMAT ØN THIS CARD AND CØNTINUATIØN ØN PREVIØUS ØNE.

350 *** USER WARNING MESSAGE 350, ØNLY NASTRAN GENERAL PURPØSE PLØTTER IS SUPPØRTED.

SC and CALCØMP plotters are no longer supported. Plotter will default to NASTPLT for the run.

351 (1) *** USER FATAL MESSAGE 351, KEYWØRD **** NØT FØUND.

A keyword required on the preceding plot command card was not present.

351 (2) *** USER FATAL MESSAGE 351, KEYWØRD **** NØT RECØGNIZED.

The indicated keyword on the preceding card was not recognized.

352 *** USER FATAL MESSAGE 352, CØØRDINATE AXES INCØRRECTLY DEFINED.

The coordinate axes for the plot are incorrectly specified on the preceding AXES or PLØT card.

353 *** USER FATAL MESSAGE 353, INCØRRECT FØRMAT.

The format of the preceding plot control card is incorrect. Refer to Section 4.2 for the correct format.

354 *** USER WARNING MESSAGE 354, **** IDENTIFICATIØN NUMBER NØT DEFINED.

A required SET, ØRIGIN, PEN, DENSITY or SYMBØL identification number was not specified. Default will be used.

355 *** USER FATAL MESSAGE 355, DATA TYPE IS INCØRRECT.

The type of a parameter value was incorrectly specified on the previous card.

356 *** USER FATAL MESSAGE 356, ØNE ØR MØRE REQUIRED REAL VALUES MISSING.

357 *** USER WARNING MESSAGE 357, CAMERA ØPTIØN NØT SPECIFIED.

358 *** USER FATAL MESSAGE 358, THRU MUST BE PRECEDED AND FØLLØWED BY INTEGER VALUES.

359 *** USER FATAL MESSAGE 359, THRU RANGE ØVERLAPS RANGE ØF PREVIØUS THRU.

360 *** USER FATAL MESSAGE 360, ØNLY DEFØRMATIØN VALID WITH ****.

The keywords VELØCITY or ACCELERATIØN may not be used with keywords STATIC, MØDAL or CMØDAL.

361 *** USER FATAL MESSAGE 361, CCØNEAX ID = ****. ØUT ØF 1 TØ 9999 PERMISSIBLE RANGE.

362 (1) *** USER FATAL MESSAGE 362, MINIMUM PRØBLEM REQUIRES **** CARD. NØNE FØUND.

362 (2) *** USER FATAL MESSAGE 362, MINIMUM PRØBLEM REQUIRES ****, **** ØR **** CARD. NØNE FØUND.

363 *** USER FATAL MESSAGE 363, RAN ØUT ØF ØPEN CØRE READING **** FILE IN **** SUBRØUTINE.

Increase Region Size, Field Length, HICØRE allocation or the length of the open core CØMMØN block, depending on the machine being used.

364 *** USER FATAL MESSAGE 364, HARMØNIC NUMBER **** ØN **** CARD. ØUT ØF 0 TØ **** ALLØWABLE RANGE.

365 *** USER FATAL MESSAGE 365, RING ID **** ØN **** CARD ØUT ØF 1 TØ 999999 ALLØWABLE RANGE.

366 *** USER FATAL MESSAGE 366, SPCAX ØR MPCAX CARD HAS SETID = 101 ØR 102. 101 AND 102 ARE SYSTEM ID-S RESERVED FØR SINE AND CØSINE SETS.

367 *** USER FATAL MESSAGE 367, CØMPØNENT SPECIFICATIØN **** ØN **** CARD IS INCØRRECT.

368 *** USER FATAL MESSAGE 368, RINGAX CARD WITH RING ID = **** HAS A ZERØ RADIUS SPECIFIED.

501 *** SYSTEM FATAL MESSAGE 501, MED TABLE INCØRRECT FØR THIS SØLUTIØN.

Input to subroutine XSBSET is incorrect. Look for format error in array SS.

502 *** USER FATAL MESSAGE 502, ILLEGAL SUBSET NUMBER FØR THIS SØLUTIØN.

User specified an incorrect subset number on SØL control card.

503 *** USER FATAL MESSAGE 503, ILLEGAL SØLUTIØN NUMBER.

User specified an incorrect solution number on SØL control card.

504 *** USER FATAL MESSAGE 504, CANNØT CHANGE FRØM SØLUTIØN *** TØ SØLUTIØN ***.

505 *** USER FATAL MESSAGE 505, CØNTRØL CARD **** IS ILLEGAL.

The card preceding Message 505 cannot be processed correctly.

506 *** USER FATAL MESSAGE 506, CØNTRØL CARD **** DUPLICATED.

The card preceding Message 506 cannot be input more than once.

507 *** USER FATAL MESSAGE 507, ILLEGAL SPECIFICATIØN ØR FØRMAT ØN PRECEDING CARD.

508 *** USER FATAL MESSAGE 508, PRØBLEM TAPE MUST BE ØN PHYSICAL TAPE FØR CHECKPØINTING.

User requested checkpointing (i.e., CHKPNT YES) but did not specify NPTP with the FILES keyword on the NASTRAN card. Therefore, the Problem Tape must be setup on tape drive.

509 *** USER FATAL MESSAGE 509, WRØNG ØLD PRØBLEM TAPE MØUNTED. ØLD PRØBLEM TAPE ID = ********, ********,**/**/**, REEL NØ. = ***.

The Old Problem Tape identification does not match the identification on the RESTART restart card.

510 *** SYSTEM FATAL MESSAGE 510, CHECKPØINT DICTIØNARY EXCEEDS CØRE SIZE - REMAINING RESTART CARDS IGNØRED.

You have run out of open core. If approach is DMAP, try putting restart deck before DMAP sequence. If this does not solve the problem, or if approach is not DMAP, then you must decrease the size of the restart deck.

511 *** SYSTEM FATAL MESSAGE 511, DMAP SEQUENCE EXCEEDS CØRE SIZE - REMANING DMAP INSTRUCTIØNS IGNØRED.

You have run out of open core. Split the DMAP sequence somewhere prior to where message 511 was printed out.

512 *** USER FATAL MESSAGE 512, ØLD PRØBLEM TAPE IS MISSING AND IS NEEDED FØR RESTART.

The Problem Tape corresponding to identification on RESTART control card must be setup on the unit assigned to the Old Problem Tape.

513 *** USER FATAL MESSAGE 513, ALTER SEQUENCE NUMBERS ARE ØUT ØF ØRDER.

514 *** USER FATAL MESSAGE 514, ENDALTER CARD IS MISSING.

ALTER deck must end with the ENDALTER control card.

515 *** USER FATAL MESSAGE 515, END INSTRUCTIØN MISSING IN DMAP SEQUENCE.

DMAP sequence must end with the END control card.

516 *** USER FATAL MESSAGE 516, UMF TAPE MUST BE MØUNTED ØN PHYSICAL TAPE DRIVE.

The UMF tape must be setup on the unit assigned to it as UMF was not specified with the FILES keyword on the NASTRAN card.

517 *** USER FATAL MESSAGE 517, WRØNG UMF TAPE MØUNTED - TAPE ID = ****.

The tape identification number on the UMF tape does not match the tape identification number on the UMF control card.

518 *** USER FATAL MESSAGE 518, CANNØT USE UMF TAPE FØR RESTART.

519 *** USER FATAL MESSAGE 519, ID CARD MUST PRECEDE ALL ØTHER CØNTRØL CARDS.

520 *** USER FATAL MESSAGE 520, CØNTRØL CARD **** IS MISSING.

521 *** USER FATAL MESSAGE 521, SPECIFY A SØLUTIØN ØR A DMAP SEQUENCE BUT NØT BØTH.

You must either select a DMAP sequence from the library by using the SØL control card or by supplying your own DMAP sequence. Do one or the other, but not both.

522 *** USER FATAL MESSAGE 522, NEITHER A SØL CARD NØR A DMAP SEQUENCE WAS INCLUDED.

See Message 521.

523 *** USER FATAL MESSAGE 523, ENDALTER CARD ØUT ØF ØRDER.

The ENDALTER control card must be preceded by the ALTER deck.

524 *** SYSTEM FATAL MESSAGE 524, ALTERNATE RETURN TAKEN WHEN ØPENING FILE ****.

This occurs if the file name is not in the FIST or the end of tape was reached while writing on the file. The file name should correspond to one of the permanent entries in the FIST.

525 *** SYSTEM FATAL MESSAGE 525, ILLEGAL FØRMAT ENCØUNTERED WHILE READING FILE ****.

File is not in the correct format. Either the wrong tape was mounted or it does not contain what you think it should.

526 *** USER FATAL MESSAGE 526, CHECKPØINT DICTIØNARY ØUT ØF SEQUENCE - REMAINING RESTART CARDS IGNØRED.

The checkpoint dictionary which follows the RESTART control card must be sequenced according to first number on each card.

527 *** USER FATAL MESSAGE 527, DUPLICATE SUBSET NUMBER *****.

528 *** USER WARNING MESSAGE 528, FACTØR FMID IN FLFACT SET **** DØES NØT LIE BETWEEN F1 AND FNF. IT IS BEING RESET TØ (F1 + FNF)/2.0.

The error may be either on a FLFACT card or on an AEFACT card.

529 *** USER FATAL MESSAGE 529, MISSING CEND CARD.

601 *** USER FATAL MESSAGE 601, THE KEYWØRD ØN THE ABØVE CARD IS ILLEGAL ØR MISSPELLED. SEE THE FØLLØWING LIST FØR LEGAL KEY WØRDS.

Case Control expects each card to begin with a keyword (usually 4 characters in length). Your card does not. User Message 612 will list the legal keywords along with a brief

description of function. To remove the error, consult Message 612 of NASTRAN Case Control card descriptions, Section 2.3, and spell your request correctly.

602 *** USER WARNING MESSAGE 602, TWØ ØR MØRE ØF THE ABØVE CARD TYPES DETECTED WHERE ØNLY ØNE IS LEGAL. THE LAST FØUND WILL BE USED.

Remove the card with the duplicate meaning. Note that some cards have alternate forms.

603 *** USER FATAL MESSAGE 603, THE ABØVE CARD DØES NØT END PRØPERLY. CØMMENTS SHØULD BE PRECEDED BY A DØLLAR SIGN.

Case Control cards of the form, name = value, should not contain more than one value. Refer to Section 2.3 for a complete description of the card or precede your comments with a dollar sign.

604 *** USER FATAL MESSAGE 604, THE ABØVE CARD HAS A NØNINTEGER IN AN INTEGER FIELD.

Consult Section 2.3 for legal values.

605 *** USER FATAL MESSAGE 605, A SYMSEQ ØR SUBSEQ CARD APPEARS WITHØUT A SYMCØM ØR SUBCØM CARD.

SYMSEQ or SUBSEQ cards must appear in a subcase defined by a SYMCØM or SUBCØM card. Check your Case Control Deck order and relabel your combination subcase.

606 *** USER FATAL MESSAGE 606, A REQUEST FØR TEMPERATURE DEPENDENT MATERIALS ØCCURS AT THE SUBCASE LEVEL. ØNLY ØNE ALLØWED PER PRØBLEM.

Only one temperature field for materials is allowed per NASTRAN run. The last specified will be used for the entire run. If additional ones are desired, a modified restart is in order.

607 *** USER FATAL MESSAGE 607, A REPCASE SUBCASE MUST BE PRECEDED BY A SUBCASE ØR SYM SUBCASE.

A REPCASE subcase is an attempt to re-output the previously computed case; therefore it cannot be the first subcase.

608 *** USER FATAL MESSAGE 608, THE SET ID SPECIFIED ØN THE ABØVE CARD MUST BE DEFINED PRIØR TØ THIS CARD.

Set identification numbers must be specified prior to their use. Also, sets specified within a subcase die at the end of the subcase. Redefine set (or define set) or move set out of subcase.

609 *** USER FATAL MESSAGE 609, SUBCASE DELIMITER CARDS MUST HAVE A UNIQUE IDENTIFYING INTEGER.

Subcase type cards must have an identifying integer. These numbers must be strictly increasing. Renumber your subcase cards. The use of a nonblank delimiter (e.g., "=") will also cause this message to occur.

610 *** USER WARNING MESSAGE 610, NØ SET ID SPECIFIED. ALL WILL BE ASSUMED.

611 *** USER FATAL MESSAGE 611, TEN CARDS HAVE ILLEGAL KEYWØRDS. NASTRAN ASSUMES BEGIN BULK CARD IS MISSING. IT WILL NØW PRØCESS YØUR BULK DATA.

Only ten key words may be misspelled. A common source of this error may be the omission of the ØUTPUT(PLØT), ØUTPUT(XYØUT) or ØUTPUT(XYPLØT) delimiter cards.

612 *** USER FATAL MESSAGE 612, --LIST ØF LEGAL CASE CØNTRØL MNEMØNICS.

This message is caused by Messages 601 or 611.

613 *** USER FATAL MESSAGE 613, THE ABØVE SET CØNTAINS 'EXCEPT' WHISH IS NØT PRECEDED BY 'THRU'.

Only identification numbers included in THRU statements may be excepted. Simplify your SET request.

614 *** USER FATAL MESSAGE 614, THE ABØVE SET IS INCØRRECTLY SPECIFIED. CHECK FØRMAT ØN THIS ØR PREVIØUS CARD.

The grammar of the SET list is incorrect or a continuation card is missing.

615 *** USER FATAL MESSAGE 615, AN IMPRØPER ØR NØ NAME GIVEN TØ THE ABØVE SET.

SET lists must have integer names. This SET list does not have one. SET 10 = is the correct format. Give the SET a corre t integer name.

616 *** USER FATAL MESSAGE 616, ELEMENT IN TH U RANGE LIES IN RANGE ØF PREVIØUS THRU ØR EXCEPT. MISSING ELEMENT ØR INCØRRECT USE ØF TH RU.

EXCEPT in SET list can only be followed by integers. An integer larger than THRU pair terminates THRU. Either list exceptions explicitly, use 2 THRUs or terminate first THRU.

617 *** USER FATAL MESSAGE 617, INCØRRECT ØR MISSING VALUE ØN CASE CØNTRØL CARD. CHECK FØR CØRRECT CARD FØRMAT.

Most integer values in Case Control must be positive. The above card either has a negative integer or a BCD value in place of a positive integer. Check the Case Control Deck documentation in Section 2.3 for the proper card format.

618 *** USER FATAL MESSAGE 618, PLØTTER ØUTPUT IS REQUESTED BUT THE PRØPER PLØT TAPE IS NØT A PHYSICAL TAPE.

Neither PLT1 or PLT2 is a physical tape. Remove the plot control packet or set up the appropriate tape.

619 *** USER WARNING MESSAGE 619, SET MEMBER *** BELØNGS TØ *** THRU ***.

A set member is already included in a THRU. The individual member will be absorbed in the THRU.

620 *** USER WARNING MESSAGE 620, SET MEMBER *** IS DUPLICATED IN SET LIST.

A set member is listed twice. The second reference will be deleted.

621 *** USER WARNING MESSAGE 621, INTERVAL *** THRU *** ØVERLAPS INTERVAL *** THRU ***. THE MAXIMUM INTERVAL WILL BE USED.

622 *** USER FATAL MESSAGE 622, REAL VALUES NØT ALLØWED IN A THRU SEQUENCE.

623 *** USER FATAL MESSAGE 623, UNEXPECTED END-ØF-RECØRD ØN CASE CØNTRØL CARD. CHECK FØR CØRRECT CARD FØRMAT.

624 *** USER FATAL MESSAGE 624, BEGIN BULK CARD NØT FØUND.

625 *** USER FATAL MESSAGE 625, TØØ LARGE ID ØN PRECEDING SUBCASE TYPE CARD. ALL ID-S MUST BE LESS THAN 99,999,999.

Reduce the size of your subcase identification number. Note also that BCD subcase identification numbers are not legal.

626 *** USER FATAL MESSAGE 626, VALUES IN EXCEPT MUST BE SPECIFIED IN ASCENDING ØRDER.

627 *** USER FATAL MESSAGE 627, THE ABØVE SUBCASE HAS BØTH A STATIC LØAD AND A REAL EIGENVALUE METHØD SELECTIØN -- REMØVE ØNE.

Rigid Formats 5 and 13 require static load and METHØD selections in the Case Control Deck. Both a load and a METHØD selection cannot take place in the same subcase. See Sections 3.6.4 and 3.14.4, respectively, for subcase requirements.

628 *** USER FATAL MESSAGE 628, THERMAL, DEFØRMATIØN, AND EXTERNAL LØADS CANNØT HAVE THE SAME SET IDENTIFICATIØN NUMBER.

Set IDs specified on the LØAD, TEMP(LØAD) and DEFØRM Case Control cards must be unique.

629 *** USER WARNING MESSAGE 629, ECHØ CARD HAS REPEATED ØR UNRECØGNIZABLE SPECIFICATIØN DATA-REPEATED SPECIFICATIØNS WILL BE IGNØRED, UNRECØGNIZABLE SPECIFICATIØNS WILL BE TREATED AS SØRT.

630 *** USER WARNING MESSAGE 630, ECHØ CARD WITH -NØNE- SPECIFICATIØN HAS ADDITIØNAL SPECIFICATIØNS WHICH WILL BE IGNØRED.

631 *** USER FATAL MESSAGE 631, PLØT AND/ØR SET CØMMAND CARD MISSING FRØM STRUCTURE PLØTTER ØUTPUT PACKAGE.

At least one SET and one PLØT card must be included after an ØUTPUT(PLØT) card.

632 *** USER FATAL MESSAGE 632, XYPLØT CØMMAND CARDS FØUND IN STRUCTURE PLØTTER ØUTPUT PACKAGE.

Plot command cards intended for an ØUTPUT(XYPLØT) or ØUTPUT(XYØUT) package may not be used in an ØUTPUT(PLØT) package. Check for missing ØUTPUT(XYPLØT) or ØUTPUT(XYØUT) card.

651 *** SYSTEM FATAL MESSAGE 651, LØGIC ERRØR IN SUBRØUTINE IFP1B WHILE PRØCESSING SET DATA ØN **** FILE.

675 *** USER FATAL MESSAGE 675, ABØVE CARD DØES NØT BEGIN WITH A NØNNUMERIC WØRD.

676 *** USER FATAL MESSAGE 676, **** IS NØT RECØGNIZED AS AN XYPLØT CØMMAND CARD ØR PARAMETER.

677 *** USER FATAL MESSAGE 677, ILLEGAL VALUE SPECIFIED.

678 *** USER FATAL MESSAGE 678, *** CØNTRADICTS PREVIØUS DEFINITIØN.

679 *** USER FATAL MESSAGE 679, *** DELIMITER ILLEGALLY USED.

680 *** USER FATAL MESSAGE 680, **** ILLEGAL IN STATEMENT.

681 *** USER FATAL MESSAGE 681, **** IS ILLEGAL IN STATEMENT.

682 *** USER FATAL MESSAGE 682, **** IS ILLEGAL IN STATEMENT.

683 *** USER FATAL MESSAGE 683, TØØ MANY SUBCASES. MAXIMUM = 200 ØN ANY ØNE XY-ØUTPUT CØMMAND CARD.

684 *** USER FATAL MESSAGE 684, SUBCASE-ID IS LESS THAN 1 ØR IS NØT IN ASCENDING ØRDER.

685 *** USER FATAL MESSAGE 685, **** = PØINT ØR ELEMENT ID IS ILLEGAL (LESS THAN 1).

686 *** USER FATAL MESSAGE 686, NEGATIVE ØR ZERØ CØMPØNENTS ARE ILLEGAL.

687 *** USER FATAL MESSAGE 687, ALPHA-CØMPØNENTS ARE NØT PERMITTED FØR STRESS ØR FØRCE XY-ØUTPUT REQUESTS.

An XYPLØT command for stresses and forces cannot have alphabetic characters in the item code. See the tables in Section 4.3.2.5 for the proper format.

688 *** USER FATAL MESSAGE 688, **** CØMPØNENT NAME NØT RECØGNIZED.

689 *** USER FATAL MESSAGE 689, LAST CARD ENDED WITH A DELIMITER BUT NØ CØNTINUATIØN CARD WAS

PRESENT.

690 *** USER FATAL MESSAGE 690, TYPE ØF CURVE WAS NØT SPECIFIED. (E.G., DISPLACEMENT, STRESS, ETC.)

691 *** USER FATAL MESSAGE 691, MØRE THAN 2 ØR UNEQUAL NUMBER ØF CØMPØNENTS FØR IDENTIFICATIØN NUMBERS WITHIN A SINGLE FRAME.

692 *** USER FATAL MESSAGE 692, XY-ØUTPUT CØMMAND IS INCØMPLETE.

693 *** USER FATAL MESSAGE 693, INSUFFICIENT CØRE FØR SET TABLE. AT LEAST **** MØRE WØRDS NEEDED.

694 *** USER FATAL MESSAGE 694, AUTØ ØR PSDF REQUESTS MAY NØT USE SPLIT FRAME, THUS ØNLY ØNE CØMPØNENT PER ID IS PERMITTED.

695 *** USER FATAL MESSAGE 695, CØMPØNENT VALUE = **** IS ILLEGAL FØR AUTØ ØR PSDF VECTØR REQUESTS.

696 *** USER FATAL MESSAGE 696, CØMPØNENT VALUE = ******** IS ILLEGAL FØR VECTØR TYPE SPECIFIED.

697 *** USER FATAL MESSAGE 697, XYPLØT, XYPRINT, XYPUNCH, XYPEAK, ØR XYPAPLØT CARD NØT FØUND IN XY PLØTTER ØUTPUT PACKAGE.

697 *** USER WARNING MESSAGE 697, SET **** NØT DEFINED. FIRST SET DEFINED WILL BE USED.

698 *** USER FATAL MESSAGE 698, NØ SETS DEFINED FØR PLØTS.

699 *** USER FATAL MESSAGE 699, **** ELEMENT IS INVALID.

An element type was incorrectly specified on a plot SET card. Refer to subsection 4.2.2.4 for correct element type names.

700 *** USER FATAL MESSAGE 700, SET **** REQUESTED ØN $\begin{Bmatrix}\text{FIND}\\\text{PLØT}\end{Bmatrix}$ CARD HAS NØT BEEN DEFINED.

702 *** USER FATAL MESSAGE 702, PLØT FILE **** DØES NØT EXIST.

703 *** USER FATAL MESSAGE 703, SET **** REQUESTED ØN FIND CARD NØT IN GPSETS FILE.

969 *** USER FATAL MESSAGE 969, CØMPØNENT VALUE = **** IS ILLEGAL FØR VECTØR TYPE SPECIFIED.

975 *** USER WARNING MESSAGE 975, XYTRAN DØES NØT RECØGNIZE **** AND IS IGNØRING.

976 *** USER WARNING MESSAGE 976, ØUTPUT DATA BLØCK **** IS PURGED. XYTRAN WILL PRØCESS ALL REQUESTS ØTHER THAN PLØT.

977 *** USER WARNING MESSAGE 977, FØLLØWING NAMED DATA BLØCK IS NØT IN SØRT2 FØRMAT.

978 *** USER WARNING MESSAGE 978, XYTRAN MØDULE FINDS DATA BLØCK (****) PURGED, NULL, ØR INADEQUATE, AND IS IGNØRING XY-ØUTPUT REQUEST FØR - **** - CURVES.

979 *** USER WARNING MESSAGE 979, AN XY-ØUTPUT REQUEST FØR PØINT ØR ELEMENT ID **** - **** - CURVE IS BEING PASSED ØVER. THE ID CØULD NØT BE FØUND IN DATA BLØCK ****.

980 *** USER WARNING MESSAGE 980, INSUFFICIENT CØRE TØ HANDLE ALL DATA FØR ALL CURVES ØF THIS FRAME ID = **** CØMPØNENT = **** DELETED FRØM ØUTPUT.

981 *** USER WARNING MESSAGE 981, CØMPØNENT = **** FØR ID = **** IS TØØ LARGE. THIS CØMPØNENTS CURVE NØT ØUTPUT.

982 *** USER WARNING MESSAGE 982, FØRMAT ØF SDR3 INPUT DATA BLØCK **** DØES NØT PERMIT SUCCESSFUL SØRT2 PRØCESSING.

983 *** USER WARNING MESSAGE 983, SDR3 HAS INSUFFICIENT CØRE TØ PERFØRM SØRT2 ØN INPUT DATA BLØCK **** ØR DATA BLØCK IS NØT IN CØRRECT FØRMAT.

984 *** USER WARNING MESSAGE 984, SDR3 FINDS ØUTPUT DATA BLØCK **** PURGED.

985 *** USER WARNING MESSAGE 985, SDR3 FIND SCRATCH **** PURGED.

986 *** USER WARNING MESSAGE 986, INSUFFICIENT CØRE FØR SDR3.

991 *** USER WARNING MESSAGE 991, XYPLØT INPUT DATA FILE **** NØT FØUND. XYPLØT ABANDØNED.

The input data file probably has been purged and there were no plots to be done.

992 *** USER WARNING MESSAGE 992, XYPLØT INPUT DATA FILE I.D. RECØRDS TØØ SHØRT. XYPLØT ABANDØNED.

The input data file records have invalid word counts and further plotting is not feasible.

993 *** USER WARNING MESSAGE 993, XYPLØT FØUND ØDD NØ. ØF VALUES FØR DATA PAIRS IN FRAME ****, CURVE NØ. ****. LAST VALUE IGNØRED.

May indicate a bad input file, but plotting continues.

994 *** USER WARNING MESSAGE 994, XYPLØT ØUTPUT FILE NAME **** NØT FØUND. XYPLØT ABANDØNED.

The PLT2 file required for plotting has not been properly set up and further plotting is useless.

997 *** USER WARNING MESSAGE 997, NØ. ***. FRAME NØ. **** INPUT DATA INCØMPATIBLE. ASSUMPTIØNS MAY PRØDUCE INVALID PLØT.

NØ. *** may take any value from 1 to 4 with the following meanings:

1. Specified X maximum equals X minimum. If this value is zero, then X maximum is set to 5.0 and X minimum to -5.0, otherwise 5 times the absolute value of X maximum is added to X maximum and subtracted from X minimum.

2. Specified X maximum is smaller than X minimum. The values are reversed.

3. Same meaning as number 1 except for Y maximum and Y minimum.

4. Same meaning as number 2 except for Y maximum and Y minimum.

998 *** SYSTEM WARNING MESSAGE 998, XYPLØT PLØTTER ØR FRAME MAY NØT CHANGE FØR LØWER FRAME. XYPLØT ABANDØNED.

Camera option, size of paper and plotter type must be the same for upper and lower frames.

6.3 EXECUTIVE MODULE MESSAGES

1001 *** SYSTEM FATAL MESSAGE 1001, ØSCAR NØT FØUND IN DPL.

ØSCAR file not present (destroyed) in Data Pool Dictionary.

1002 *** SYSTEM FATAL MESSAGE 1002, ØSCAR CØNTAINS NØ MØDULES.

XSFA found no modules on ØSCAR needing file allocation.

1003 *** SYSTEM FATAL MESSAGE 1003, PØØL CØULD NØT BE ØPENED.

Data Pool File (PØØL) not present (destroyed) in FIST.

1004 *** SYSTEM FATAL MESSAGE 1004, ILLEGAL EØF ØN PØØL.

End-of-file encountered before ØSCAR file reached on Data Pool.

1011 *** SYSTEM FATAL MESSAGE 1011, MD ØR SØS TABLE ØVERFLØW.

Module description or serial ØSCAR table overflowed.

1012 *** SYSTEM FATAL MESSAGE 1012, PØØL CØULD NØT BE ØPENED.

Data Pool File (PØØL) not present (destroyed) in FIST.

1013 *** SYSTEM FATAL MESSAGE 1013, ILLEGAL EØR ØN PØØL.

ØSCAR record has illegal format.

1014 *** SYSTEM FATAL MESSAGE 1014, PØØL FILE MIS-PØSITIØNED.

ØSCAR (PØØL) file not at position passed in XSFA calling sequence.

1021 *** SYSTEM FATAL MESSAGE 1021, FIAT ØVERFLØWED.

FIAT /XFIAT/ Table overflowed - reduce number of logical files. See Section 2 of the Programmer's Manual.

1031 *** SYSTEM FATAL MESSAGE 1031, DPL ØVERFLØW.

Data Pool Dictionary /XDPL/ overflowed - increase compiled size. See Section 2 of the Programmer's Manual.

1032 *** SYSTEM FATAL MESSAGE 1032, PØØL ØR FILE BEING PØØLED/UN-PØØLED CØULD NØT BE ØPENED.

Files not present (destroyed) in FIST.

1033 *** SYSTEM FATAL MESSAGE 1033, ILLEGAL EØF ØN FILE BEING PØØLED.

File being pooled has illegal format.

1034 *** SYSTEM FATAL MESSAGE 1034, ILLEGAL EØR ØN FILE BEING PØØLED.

File being pooled has illegal format (bad header).

1035 *** SYSTEM FATAL MESSAGE 1035, EQUIV INDICATED, NØNE FØUND.

File (data block) equivalence not found as indicated by XSFA.

1041 *** SYSTEM FATAL MESSAGE 1041, ØLD/NEW PØØL CØULD NØT BE ØPENED.

Files not present (destroyed) in FIST.

1051 *** SYSTEM FATAL MESSAGE 1051, FIAT ØVERFLØW.

FIAT /XFIAT/ overflowed - reduce number of logical files. See Section 2 of the Programmer's Manual.

1101 *** USER FATAL MESSAGE 1101, CØULD NØT ØPEN FILE NAMED ********.

Data block has not been generated.

1102 *** SYSTEM FATAL MESSAGE 1102, CØULD NØT ØPEN FILE NAMED ********.

Problem Tape (NPTP) or Pool Table (PØØL) File linkage is broken. Look for error in /XFIST/, /XPFIST/ or /XXFIAT/.

1103 *** SYSTEM FATAL MESSAGE 1103, UNABLE TØ PØSITIØN DATA PØØL FILE CØRRECTLY.

Contents of /XDPL/ do not correspond to contents of PØØL file.

1104 *** SYSTEM FATAL MESSAGE 1104, FDICT TABLE IS INCØRRECT.

Subroutine XCHK is not generating FDICT correctly.

1105 *** USER FATAL MESSAGE 1105, CANNØT FIND DATA BLØCK NAMED ******** HEADER RECØRD = ********.

Data block name or equivalenced data block name must match header record.

1106 *** USER FATAL MESSAGE 1106, CHECKPØINT DICTIØNARY ØVERFLØWED THERE IS NØ MØRE CØRE AVAILABLE.

Restart problem from this point with dictionary available.

1107 *** SYSTEM FATAL MESSAGE 1107, CANNØT FIT DATA BLØCK NAMED ******** ØN TWØ PRØBLEM TAPE REELS.

Use full tape reels for Problem Tape.

1108 *** SYSTEM FATAL MESSAGE 1108, PURGE TABLE ØVERFLØWED.

Reduce the number of data blocks being checkpointed at one time by replacing a single CHKPNT instruction with two CHKPNT instructions.

1109 *** SYSTEM FATAL MESSAGE 1109, CANNØT FIND DATA BLØCK NAMED NXPTDC HEADER RECØRD = ********.

Problem Tape is not positioned correctly for reading NXPTDC. Problem is in subroutine which previously wrote NXPTDC onto Problem Tape. Suspect subroutine is XGPI, XCEI or XCHK.

1126 *** SYSTEM FATAL MESSAGE 1126, ADDRESS ØF BUFFER LESS THAN ADDRESS ØF /XNSTRN/.

Highly unlikely. Program bug or machine error.

1127 *** SYSTEM FATAL MESSAGE 1127, BUFFER ASSIGNED EXTENDS INTØ MASTER INDEX AREA.

Calling program bug in buffer allocation or first word of /SYSTEM/ has been altered.

1128 *** SYSTEM FATAL MESSAGE 1128, ØN AN ØPEN CALL WITHØUT REWIND, THE BLØCK NUMBER READ DØES NØT MATCH EXPECTED VALUE.

Probably I/Ø Error.

1129 *** SYSTEM FATAL MESSAGE 1129, ØN A CALL WRITE THE WØRD CØUNT IS NEGATIVE.

Definite calling program error.

1130 *** SYSTEM FATAL MESSAGE 1130, ØN A CALL READ THE CØNTRØL WØRD AT WHICH THE FILE IS PØSITIØNED IS NØT ACCEPTABLE.

Attempt to read string formatted record which is not allowed.

1131 *** SYSTEM FATAL MESSAGE 1131, LØGICAL RECØRD TRAILER NØT RECØGNIZABLE AS SUCH.

Probable GINØ bug or hardware error.

1132 *** SYSTEM FATAL MESSAGE 1132, UNRECØGNIZABLE CØNTRØL WØRD DURING PRØCESSING ØF A BCKREC CALL.

Probable GINØ bug or hardware error.

1133 *** SYSTEM FATAL MESSAGE 1133, AFTER A PØSITIØNING CALL TØ IØ6600, DURING PRØCESSING ØF A BCKREC CALL THE BLØCK READ WAS NØT THE EXPECTED ØNE.

Probable IØ6600 bug or possible I/Ø error.

1134 *** SYSTEM FATAL MESSAGE 1134, CALL SKPFIL IN A FØRWARD DIRECTIØN ØN A FILE NØT ØPENED FØR ØUTPUT IS NØT SUPPØRTED.

1135 *** SYSTEM FATAL MESSAGE 1135, FILPØS WAS CALLED ØN A FILE ØPENED FØR ØUTPUT.

1136 *** SYSTEM FATAL MESSAGE 1136, ENDPUT WAS CALLED WITH BLØCK (8) = -1.

Most likely PUTSTR was not called first.

1137 *** SYSTEM FATAL MESSAGE 1137, MØRE TERMS WRITTEN IN STRING THAN WERE AVAILABLE TØ WRITE.

Most likely subroutine logic error.

1138 *** SYSTEM FATAL MESSAGE 1138, CURRENT BUFFER PØINTER EXCEEDS LAST DATA WØRD IN BLØCK.

Probably a bug in PUTSTR in the computation of the number of terms available to write in a string.

1139 *** SYSTEM FATAL MESSAGE 1139, ØN AN INITIAL CALL TØ GETSTR, THE RECØRD IS NØT PØSITIØNED AT THE CØLUMN HEADER.

Either the record is not a string formatted record, or the calling routine has not made a proper sequence of GETSTR, ENDGET calls.

1140 *** SYSTEM FATAL MESSAGE 1140, STRING DEFINITIØN WØRD NØT RECØGNIZABLE.

Probable cause is a failure to call ENDGET to complete processing of the previous string.

1141 *** SYSTEM FATAL MESSAGE 1141, FIRST WØRD ØF A DØUBLE PRECISIØN STRING IS NØT ØN A DØUBLE PRECISIØN BØUNDARY.

This error is probably due to a bug in any of PUTSTR, ØPEN or NASTIØ, all of which have responsibility for ensuring proper alignment.

1142 *** SYSTEM FATAL MESSAGE 1142, CURRENT BUFFER PØINTER IS BEYØND RANGE ØF INFØRMATIØN IN BUFFER.

Either an attempt to read beyond end-of-information or a GINØ logic bug.

1143 *** SYSTEM FATAL MESSAGE 1143, ØN AN INITIAL CALL TØ GETSTB, THE FILE IS NØT PØSITIØNED AT AN ACCEPTABLE PØINT.

File should be positioned at the beginning of record or at end-of-file.

1144 *** SYSTEM FATAL MESSAGE 1144, END-ØF-SEGMENT CØNTRØL WØRD SHØULD HAVE IMMEDIATELY PRECEDED CURRENT PØSITIØN AND IT DID NØT.

GINØ logic error.

1145 *** SYSTEM FATAL MESSAGE 1145, CØLUMN TRAILER NØT FØUND.

Previous record to be read backwards is not a string formatted record.

1146 *** SYSTEM FATAL MESSAGE 1146, PREVIØUS RECØRD TØ BE READ BACKWARDS WAS NØT WRITTEN WITH STRING TRAILERS.

1147 *** SYSTEM FATAL MESSAGE 1147, STRING RECØGNITIØN WØRD NØT RECØGNIZED.

A subroutine may not have called GETSTB to indicate completion of processing of previous string or a bug in GETSTB logic.

1148 *** SYSTEM FATAL MESSAGE 1148, RECØRD CØNTRØL WØRD NØT IN EXPECTED PØSITIØN.

Logic error in GETSTB or PUTSTR when string was written.

1149 *** SYSTEM FATAL MESSAGE 1149, RECTYP WAS CALLED FØR A FILE ØPENED FØR ØUTPUT.

Not allowed.

1150 *** SYSTEM FATAL MESSAGE 1150, RECTYP MUST BE CALLED WHEN THE FILE IS PØSITIØNED AT THE BEGINNING ØF A RECØRD.

1151 *** SYSTEM FATAL MESSAGE 1151, ØN A CALL TØ ØPEN THE BUFFER ASSIGNED ØVERLAPS A PREVIØUSLY ASSIGNED BUFFER.

1152 *** SYSTEM FATAL MESSAGE 1152, CALL TØ ØPEN FØR AN ALREADY ØPEN FILE.

1153 *** SYSTEM FATAL MESSAGE 1153, FILE NØT ØPEN.

1154 *** SYSTEM FATAL MESSAGE 1154, GINØ REFERENCE NAME NØT IN FIST ØR FILE NØT ØPEN.

1155 *** SYSTEM FATAL MESSAGE 1155, CALL TØ GETSTR ØCCURRED WHEN THE FILE WAS PØSITIØNED AT END-ØF-FILE.

1156 *** SYSTEM FATAL MESSAGE 1156, ATTEMPTED TØ WRITE ØN AN INPUT FILE.

1157 *** SYSTEM FATAL MESSAGE 1157, ATTEMPTED TØ READ FRØM AN ØUTPUT FILE.

1158 *** SYSTEM FATAL MESSAGE 1158, A CALL TØ BLDPK ØR PACK IN WHICH EITHER TYPIN ØR TYPØUT IS ØUT ØF RANGE.

1159 *** SYSTEM FATAL MESSAGE 1159, RØW PØSITIØNS ØF ELEMENTS FURNISHED TØ ZBLPKI ØR BLDPKI ARE NØT IN MØNØTØNIC INCREASING SEQUENCE.

1160 *** SYSTEM FATAL MESSAGE 1160, ØN A CALL TØ BLDPKN, FILE NAME DØES NØT MATCH PREVIØUS CALLS.

BLDPK was not called prior to a call to BLDPKN.

1161 *** SYSTEM FATAL MESSAGE 1161, A CALL TØ INTPK ØR UNPACK IN WHICH TYPØUT IS ØUT ØF RANGE.

1162 *** SYSTEM FATAL MESSAGE 1162, ØN AN ATTEMPT TØ READ A SUBINDEX AT THE TIME ØF A CALL TØ ØPEN AN END-ØF-FILE WAS ENCØUNTERED ØR WRØNG NUMBER ØF WØRDS READ.

The file has never been written and IØ6600 failed to detect it; possible I/Ø error.

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1163 *** SYSTEM FATAL MESSAGE 1163, A READ ATTEMPT WHEN THE CØRRESPØNDING SUBINDEX IS ZERØ.

Normally this indicates an attempt to read past the end-of-information. However, if called from FILPØS, suspect is subroutine error in saving and returning a correct file position.

1164 *** SYSTEM FATAL MESSAGE 1164, FØLLØWING A READ ATTEMPT ØN AN INDEXED FILE, EITHER AN END-ØF-FILE WAS ENCØUNTERED ØR THE NUMBER ØF WØRDS READ WAS INCØRRECT.

I/Ø error.

1165 *** SYSTEM FATAL MESSAGE 1165, ØN AN ATTEMPT TØ READ A SEQUENTIAL FILE, AN END-ØF-FILE ØR AN END-ØF-INFØRMATIØN WAS ENCØUNTERED.

1166 *** SYSTEM FATAL MESSAGE 1166, ØN AN ATTEMPT TØ READ A SEQUENTIAL FILE, A LØNG RECØRD WAS ENCØUNTERED.

1167 *** SYSTEM FATAL MESSAGE 1167, ØN AN ATTEMPT TØ READ A SEQUENTIAL FILE, A SHØRT RECØRD WAS ENCØUNTERED.

1168 *** SYSTEM FATAL MESSAGE 1168, A CALL TØ IØ6600 WITH ØPCØDE=5 (FØRWARD SPACE) IS NØT SUPPØRTED.

1169 *** SYSTEM FATAL MESSAGE 1169, ILLEGAL CALL TYPE, LØGIC ERRØR IN IØ6600.

1170 *** SYSTEM FATAL MESSAGE 1170, ILLEGAL CALL TØ NASTIØ, LØGIC ERRØR IN IØ6600.

1171 *** SYSTEM FATAL MESSAGE 1171, ØN A PØSITIØN CALL, THE BLØCK NUMBER REQUESTED IS NØT FØUND IN CØRE WHEN IT IS EXPECTED THERE.

Either the caller has written in the area furnished to NASTIØ or there is a logic error in NASTIØ.

1172 *** SYSTEM FATAL MESSAGE 1172, WHEN ATTEMPTING TØ READ A NEW INDEX, THE NUMBER ØF WØRDS RETURNED WAS INCØRRECT.

Either an I/Ø error or logic error in NASTIØ.

1201 *** SYSTEM FATAL MESSAGE 1201, FIAT ØVERFLØW.

FIAT /XFIAT/ overflowed - reduce number of logical files. See Section 2.4 of the Programmer's Manual.

1202 *** SYSTEM FATAL MESSAGE 1202, DPL ØVERFLØW.

Data Pool Dictionary /XDPL/ overflowed - increase compiled size. See Section 2.4 of the Programmer's Manual.

1300 *** SYSTEM FATAL MESSAGE 1300, END-ØF-FILE WAS CALLED ØN A FILE ØPEN FØR INPUT.

1301 *** SYSTEM FATAL MESSAGE 1301, END-ØF-FILE ENCØUNTERED.

An error in the calling program caused an unexpected end-of-file.

1302 *** SYSTEM FATAL MESSAGE 1302, ZERØ LENGTH RECØRD SEGMENT ENCØUNTERED.

A zero length record segment occurred before the last record in a block.

1303 *** SYSTEM FATAL MESSAGE 1303, ATTEMPT TØ GET A STRING PRIØR TØ INFØRMATIØN.

There is an error in the calling program.

1304 *** SYSTEM FATAL MESSAGE 1304, UNRECØGNIZED CØNTRØL WØRD.

The calling program may have overwritten a buffer.

1305 *** SYSTEM FATAL MESSAGE 1305, BLØCK NUMBER CHECK FAILED.

In the process of making a data block core resident, the block number did not have the expected value.

1306 *** SYSTEM FATAL MESSAGE 1306, BLØCK NUMBER IN BLØCK TØ BE WRITTEN DØES NØT MATCH NUMBER IN FILE CØNTRØL BLØCK.

1307 *** SYSTEM FATAL MESSAGE 1307, BLØCK NUMBER ØF BLØCK TØ BE WRITTEN IS NØT IN CURRENT UNIT.

The block number was not in the current unit and not equal to the block number in the preceding unit.

1308 *** SYSTEM FATAL MESSAGE 1308, ATTEMPT TØ READ BEYØND DATA.

1309 *** SYSTEM FATAL MESSAGE 1309, CØRE RESIDENT DATA BLØCK NUMBER DØES NØT MATCH NUMBER IN FILE CØNTRØL BLØCK.

1310 *** SYSTEM FATAL MESSAGE 1310, PØINTER TØ NEXT CØRE RESIDENT DATA BLØCK IS ZERØ.

Next block should be in core.

1311 *** SYSTEM FATAL MESSAGE 1311, BLØCK NUMBER TØ BE READ IS NØT INCLUDED IN CURRENT CHAIN ØF UNITS.

1312 *** SYSTEM FATAL MESSAGE 1312, BLØCK NUMBER ØF BLØCK READ FRØM DISK DØES NØT MATCH NUMBER IN FILE CØNTRØL BLØCK.

1313 *** SYSTEM FATAL MESSAGE 1313, PØINTER TØ CØRE RESIDENT DATA BLØCK IS PØSITIØNED PRIØR TØ INFØRMATIØN.

1314 *** SYSTEM FATAL MESSAGE 1314, ATTEMPT TØ PØSITIØN A FILE ØPENED TØ WRITE.

1315 *** SYSTEM FATAL MESSAGE 1315, BLØCK NUMBER NØT FØUND.

Logic error in an attempt to position a core resident data block.

1316 *** SYSTEM FATAL MESSAGE 1316, NØ DATA EVENT CØNTRØL BLØCK AVAILABLE.

1317 *** SYSTEM FATAL MESSAGE 1317, ERRØR IN INTERNAL SUBRØUTINE IN NASTIØ.

1318 *** SYSTEM FATAL MESSAGE 1318, ATTEMPT TØ READ BEYØND END-ØF-DATA.

1319 *** SYSTEM FATAL MESSAGE 1319, DCB SYNCHRØNØUS ERRØR DETECTED.

Data control block improperly written.

1320 *** SYSTEM FATAL MESSAGE 1320, FIRST TERM IN RØW IS NØT A DIAGØNAL TERM.

1321 *** SYSTEM FATAL MESSAGE 1321, FIRST TERM IN RØW IS NØT A DIAGØNAL TERM.

1322 *** SYSTEM FATAL MESSAGE 1322, BAD STATUS RETURN ØN A NTRAN READ CALL.

Possible I/Ø error.

1323 *** SYSTEM FATAL MESSAGE 1323, END-ØF-DATA ENCØUNTERED.

The unit on which the end-of-data occurred is not a tape.

1324 *** SYSTEM FATAL MESSAGE 1324, INCØRRECT WØRD CØUNT ØN A NTRAN READ CALL.

Number of words read by NTRAN is incorrect.

1325 *** SYSTEM FATAL MESSAGE 1325, BAD STATUS RETURN ØN A NTRAN WRITE CALL.

Possible I/Ø error.

1326 *** SYSTEM FATAL MESSAGE 1326, INCØRRECT NUMBER ØF WØRDS PASSED BY NTRAN.

1327 *** SYSTEM FATAL MESSAGE 1327, ILLEGAL RETURN FRØM FWDREC.

1701 *** SYSTEM WARNING MESSAGE 1701, AVAILABLE CØRE EXCEEDED BY ********* LINE IMAGE BLØCKS.

1702 *** SYSTEM INFØRMATIØN MESSAGE 1702, UTILITY MØDULE SEEMAT WILL ABANDØN PRØCESSING DATA BLØCK ********.

1704 *** USER WARNING MESSAGE 1704, PLØT FILE - **** NØT SET UP.

1705 *** SYSTEM WARNING MESSAGE 1705, LØGIC ERRØR AT STATEMENT ***** IN SUBRØUTINE SEEMAT.

1706 *** USER WARNING MESSAGE 1706, PRECEDING BULK DATA DECK HAS BEEN CANCELED AND WILL NØT APPEAR ØN USER MASTER FILE.

The preceding Bulk Data Deck contains errors which preclude its inclusion on the User's Master File. Appropriate error message should appear in the echo of the Bulk Data Deck. Any subsequent Bulk Data Decks will be placed on the User's Master File if error-free.

1707 *** USER FATAL MESSAGE 1707, ILLEGAL TID VALUE ØN UMF CARD.

The TID value used on all UMF cards must be the same for any run and must match the TID value on the UMF tape being input. See Section 2.5 for details.

1708 *** SYSTEM FATAL MESSAGE 1708, UMFEDT - UNEXPECTED EØF FRØM READ.

The occurence of this message indicates a program failure in the User's Master File Editor subroutine UMFEDT.

1709 *** SYSTEM FATAL MESSAGE 1709, UMFEDT - UNEXPECTED EØF FRØM READ.

The occurence of this message indicates a program failure in the User's Master File Editor subroutine UMFEDT.

1710 *** SYSTEM FATAL MESSAGE 1710, UMFEDT UNABLE TØ ØPEN ØNE ØF THE PERMANENT NASTRAN FILES UMF, NUMF, ØR NPTP.

1711 *** USER FATAL MESSAGE 1711, NØ TAPE SETUP FØR EITHER UMF ØR NUMF. THE USER MASTER FILE EDITØR REQUIRES AT LEAST ØNE ØF THESE TAPES TØ BE SET UP.

The tape(s) required must be appropriate to the requested action. See Section 2.5 for details.

1712 *** USER WARNING MESSAGE 1712, REQUEST TØ ADD DECK WITH PRØBLEM IDENTIFICATIØN NØ. = **** CØNFLICTS WITH IMPLIED REQUEST TØ CØPY THE SAME PRØBLEM FRØM THE UMF. THE NEW DECK WILL BE USED.

This message will occur whenever a deck is added whose PID value is the same as that of a problem already existing on the old User's Master File.

1713 *** USER WARNING MESSAGE 1713, REMØVE REQUEST FØR PRØBLEM **** IS ØUT ØF SEQUENCE ØR NØT ØN UMF.

User's Master File Editor control cards must form an increasing sequence. See Section 2.5 for details.

1714 *** USER WARNING MESSAGE 1714, LIST REQUEST FØR PRØBLEM **** IS ØUT ØF SEQUENCE ØR NØT ØN UMF.

User's Master File Editor control cards must form an increasing sequence. See Section 2.5 for details.

1715 *** USER WARNING MESSAGE 1715, PUNCH REQUEST FØR PRØBLEM **** IS ØUT ØF SEQUENCE ØR NØT ØN UMF.

User's Master File Editor control cards must form an increasing sequence. See Section 2.5 for details.

1716 *** USER FATAL MESSAGE 1716, PRØBLEM WITH PID = **** IS NØT ØN UMF ØR CARD IS ØUT ØF SEQUENCE.

User's Master File Editor control cards must form an increasing sequence. See Section 2.5 for details.

1717 *** USER FATAL MESSAGE 1717, NUMF TAPE ID HAS ALREAD BEEN SPECIFIED.

The tape id value for the New User's Master File (NUMF) may only be specified once. See Section 2.5 for details.

1718 *** USER FATAL MESSAGE 1718, NUMF TAPE ID MAY NØT BE RESPECIFIED.

The tape id value for the New User's Master File (NUMF) may only be specified once. See Section 2.5 for details.

1719 *** USER WARNING MESSAGE 1719, PUNPRT REQUEST FØR PRØBLEM **** IS ØUT ØF SEQUENCE ØR NØT ØN UMF.

User's Master File Editor control cards must form an increasing sequence. See Section 2.5 for details.

1720 *** SYSTEM FATAL MESSAGE 1720, UMFEDT UNABLE TØ LØCATE BULK DATA ØN NPTP.

1721 *** USER FATAL MESSAGE 1721, BAD USER MASTER FILE EDITØR DATA CARD.

See Section 2.5 for instructions for using the User's Master File Editor.

1722 *** USER WARNING MESSAGE 1722, MISSING FINIS CARD. PRØCESSING CØNTINUING.

1723 *** Reserved for future implementation in the User's Master File Editor.

1724 *** Reserved for future implementation in the User's Master File Editor.

1725 *** Reserved for future implementation in the User's Master File Editor.

1726 *** Reserved for future implementation in the Preface.

1727 *** Reserved for future implementation in the Preface.

1728 *** Reserved for future implementation in the Preface.

1729 *** Reserved for future implementation in the Preface.

1730 *** Reserved for future implementation in the Preface.

1731 *** Reserved for future implementation in the Preface.

1732 *** Reserved for future implementation in the Preface.

1733 *** Reserved for future implementation in the Preface.

1734 *** Reserved for future implementation in the Preface.

1735 *** Reserved for future implementation in the Preface.

1736 *** Reserved for future implementation in the Preface.

1737 *** Reserved for future implementation in the Preface.

1738 *** USER FATAL MESSAGE 1738, UTILITY MØDULE INPUT FIRST PARAMETER VALUE *** ØUT ØF RANGE.

In the test problem generating version of utility module INPUT, the first parameter value specifies the specific problem type as follows:

1. Laplace circuit (an N x N array of scalar points connected by scalar springs and optionally by scalar masses).
2. Rectangular frame made from BARS or RØDS.
3. Rectangular plate made from QUAD1 elements.
4. Rectangular plate made from TRIA1 elements.
5. N-segment string modeled with scalar elements.
6. N-cell beam made from BAR elements.
7. N-order full matrix generator with optional load.
8. N-spoke wheel.

1739 *** SYSTEM FATAL MESSAGE 1739, UNABLE TØ ØPEN FILE ***.

This message can occur if a required output file is purged in utility module INPUT.

1740 *** SYSTEM FATAL MESSAGE 1740, EØF ENCØUNTERED.

An unexpected end-of-file has been encountered while reading an input data block in utility module INPUT.

1741 *** SYSTEM FATAL MESSAGE 1741, EØR ENCØUNTERED.

An unexpected end-of-record indicator has been encountered while reading an input data block in utility module INPUT.

1742 *** SYSTEM FATAL MESSAGE 1742, NØ DATA PRESENT.

Utility module INPUT - input data block contains no data records.

1743 *** SYSTEM FATAL MESSAGE 1743, EØF FRØM FWDREC.

Utility module INPUT encountered an end-of-file on an input data block while attempting to read past the header record.

1744 *** USER FATAL MESSAGE 1744, DATA CARD(S) ******** GENERATED BY UTILITY MØDULE INPUT NØT ALLØWED IN BULK DATA.

Module is not capable of integrating same card type from two sources.

1745 ***********************

Message 1745 is reserved for utility module INPUT.

6.4 FUNCTIONAL MODULE MESSAGES (2001 THRU 3000)

2001 *** USER FATAL MESSAGE 2001, SEQGP CARD REFERENCES UNDEFINED GRID PØINT ****.

2002 *** SYSTEM FATAL MESSAGE 2002, GRID PØINT **** NØT IN EQEXIN.

This message indicates a program design error in GP1.

2003 *** USER FATAL MESSAGE 2003, CØØRDINATE SYSTEM **** REFERENCES UNDEFINED GRID PØINT ****.

Applies to CØRD1j definitions.

2004 *** USER FATAL MESSAGE 2004, CØØRDINATE SYSTEM **** REFERENCES UNDEFINED CØØRDINATE SYSTEM ****.

Applies to CØRD2j definitions.

2005 *** SYSTEM FATAL MESSAGE 2005, INCØNSISTENT CØØRDINATE SYSTEM DEFINITIØN.

At least one coordinate system is so defined that it cannot be related to the basic coordinate system. See Section 4.21.7.4 of the Programmer's Manual.

2006 *** USER FATAL MESSAGE 2006, INTERNAL GRID PØINT **** REFERENCES UNDEFINED CØØRDINATE SYSTEM ****.

The grid point whose internal sequence number is printed above references an undefined coordinate system in either field 3 or field 7 of a GRID card.

2007 *** USER FATAL MESSAGE 2007, ELEMENT **** REFERENCES UNDEFINED GRID PØINT ****.

2008 *** USER FATAL MESSAGE 2008, LØAD SET **** REFERENCES UNDEFINED GRID PØINT ****.

2009 *** USER FATAL MESSAGE 2009, TEMP SET **** REFERENCES UNDEFINED GRID PØINT ****.

2010 *** USER FATAL MESSAGE 2010, ELEMENT **** REFERENCES UNDEFINED GRID PØINT ****.

2011 *** USER FATAL MESSAGE 2011, NØ PRØPERTY CARD FØR ELEMENT TYPE ****.

2012 *** USER FATAL MESSAGE 2012, GRID PØINT **** SAME AS SCALAR PØINT.

Identification numbers of grid and scalar points must be unique.

2013 *** USER WARNING MESSAGE 2013, NØ STRUCTURAL ELEMENTS EXIST.

Model checked for structural elements.

2014 *** SYSTEM FATAL MESSAGE 2014, LØGIC ERRØR IN ECPT CØNSTRUCTIØN.

The spill logic in the construction of the skeleton (TA1B) has failed. Problem could be referred to maintenance programming staff. A temporary fix may be available if additional storage can be provided to NASTRAN e.g., by increasing the region size (IBM 360).

2015 *** USER WARNING MESSAGE 2015, EITHER NØ ELEMENTS CØNNECT INTERNAL GRID PØINT ******** ØR IT IS CØNNECTED TØ A RIGID ELEMENT ØR A GENERAL ELEMENT.

The message is a warning only since the degrees of freedom associated with the point may be removed by multipoint constraints or in other ways. The internal identification number is formed by assigning to each grid point and scalar point one of the integers 1, 2, --- according to its resequenced position. It may be determined from data block EQEXIN via a DMAP TABPT instruction.

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2016 (1) *** USER INFØRMATIØN MESSAGE 2016, GIVENS TIME ESTIMATE IS ******** SECØNDS.
PRØBLEM SIZE IS ********, SPILL WILL ØCCUR FØR THIS
CØRE AT A PRØBLEM SIZE ØF ******** .

2016 (2) *** USER FATAL MESSAGE 2016, NØ MATERIAL PRØPERTIES EXIST.

2017 *** USER FATAL MESSAGE 2017, MATS1 CARD REFERENCES UNDEFINED MAT1 **** CARD.

The user should check that all MATS1 cards reference MAT1 cards that exist in the Bulk Data Deck.

2018 *** USER FATAL MESSAGE 2018, MATS2 CARD REFERENCES UNDEFINED MAT2 **** CARD.

The user should check that all MATS2 cards reference MAT2 cards that exist in the Bulk Data Deck.

2019 *** USER FATAL MESSAGE 2019, MATT1 CARD REFERENCES UNDEFINED MAT1 **** CARD.

The user should check that all MATT1 cards reference MAT1 cards that exist in the Bulk Data Deck.

2020 *** USER FATAL MESSAGE 2020, MATT2 CARD REFERENCES UNDEFINED MAT2 **** CARD.

The user should check that all MATT2 cards reference MAT2 cards that exist in the Bulk Data Deck.

2021 *** SYSTEM FATAL MESSAGE 2021, BAD GMMAT CALLING SEQUENCE.

The calling sequence of the subroutine which called either subroutine GMMATD or GMMATS defined a nonconformable matrix product. GMMATD and GMMATS examine the transpose flags in combination with the orders of the matrices to make sure that a conformable matrix product is defined by the input data. This test clearly is made for purposes of calling routine checkout only. No tests are made, nor can they be made, to ensure that the calling routine has provided sufficient storage for arrays.

2022 *** SYSTEM FATAL MESSAGE 2022, SMA-B SCALAR PØINT INSERTIØN LØGIC ERRØR.

Problem error in creating the ECPT data block in module TA1. Use the TABPT module to print ECPT.

2023 *** SYSTEM FATAL MESSAGE 2023, DETCK UNABLE TØ FIND PIVØT PØINT **** IN GPCT.

Probable error in creating the ECPT data block in module TA1. Use the TABPT module to print ECPT.

2024 *** USER FATAL MESSAGE 2024, ØPERATIØN CØDE ******** NØT DEFINED FØR MØDULE PARAM.

The use of V,N,SUB rather than C,N,SUB can cause this.

2025 *** USER FATAL MESSAGE 2025, UNDEFINED CØØRDINATE SYSTEM ****.

The coordinate system identification number transmitted via ECPT(1) could not be found in the CSTM array. The user should check coordinate system numbers used on bulk data cards against those defined on CØRD1C, CØRD1R, etc., bulk data cards to insure that there are no undefined coordinate systems.

2026 *** USER FATAL MESSAGE 2026, ELEMENT **** GEØMETRY YIELDS UNREASØNABLE MATRIX.

Referenced element geometry and/or properties yields a numerical result which causes an element stiffness or mass matrix to be undefined. Possible causes include, but are not limited to, (1) the length of a rod or bar is zero because the end points have the same

coordinates, (2) the sides of a triangle or quadrilateral are collinear which leads to a zero cross product in defining an element coordinate system, or (3) the bar orientation vector is parallel to the bar axis. Check GRID bulk data cards defining element end points for bad data.

2027 *** USER FATAL MESSAGE 2027, ELEMENT **** HAS INTERIØR ANGLE GREATER THAN 180 DEG. AT GRID PØINT ****.

SHEAR or TWIST panel element with the referenced element number has been defined with the four grid points out of the proper cyclical order. See bulk data card definitions for CSHEAR and CTWIST cards.

2028 *** SYSTEM FATAL MESSAGE 2028, SMA3A ERRØR NØ. ****.

Internal logic error in subroutine SMA3A of module SMA3. Possible error in generation of the GEI data block. Use the TABPT module to print GEI.

2029 *** USER FATAL MESSAGE 2029, UNDEFINED TEMPERATURE SET ****.

The referenced temperature set had no default temperature defined. Define a temperature or default temperature for each grid point in the model.

2030 *** SYSTEM FATAL MESSAGE 2030, BAD GPTT.

The format of the GPTT data block is incorrect. Use the TABPT module to print the GPTT data block.

2031 *** USER FATAL MESSAGE 2031, ELEMENT **** UNACCEPTABLE GEØMETRY.

2032 *** USER FATAL MESSAGE 2032, ELEMENT **** UNACCEPTABLE GEØMETRY.

2033 *** USER FATAL MESSAGE 2033, SINGULAR H-MATRIX FØR ELEMENT ****.

2034 *** SYSTEM FATAL MESSAGE 2034, ELEMENT **** SIL'S DØ NØT MATCH PIVØT.

Possible error in generation of the ECPT data block. Use the TABPT module to print ECPT.

2035 *** USER FATAL MESSAGE 2035, QUADRILATERAL **** INTERIØR ANGLE GREATER THAN 180 DEG.

2036 *** USER FATAL MESSAGE 2036, SINGULAR MATRIX FØR ELEMENT ****.

2037 *** USER FATAL MESSAGE 2037, BAD ELEMENT **** GEØMETRY.

2038 *** SYSTEM FATAL MESSAGE 2038, SINGULAR MATRIX FØR ELEMENT ****.

2039 *** USER FATAL MESSAGE 2039, ZERØ SLANT LENGTH FØR HARMØNIC **** ØF CCØNEAX ****.

2040 *** USER FATAL MESSAGE 2040, SINGULAR MATRIX FØR ELEMENT ****.

2041 *** USER FATAL MESSAGE 2041, A MATT1,MATT2,MATT3 or MATS1 CARD REFERENCES TABLE NUMBER **** WHICH IS NØT DEFINED ØN A TABLEM1, TABLEM2, TABLEM3, TABLEM4 ØR TABLES1 CARD.

The user must ensure that all table identification numbers on MATT1, MATT2, MATT3, or MATS1 cards reference tables which exist in the Bulk Data Deck.

2042 *** USER FATAL MESSAGE 2042, MISSING MATERIAL TABLE **** FØR ELEMENT ****.

The referenced material table identification number is missing. The user should check to see that all element property bulk data cards (e.g., PBAR, PRØD) reference material card identification numbers for material property cards that exist in the Bulk Data Deck.

2043 (1) *** USER WARNING MESSAGE 2043, ØFP HAS INSUFFICIENT CØRE FØR ØNE GINØ BUFFER **** ØFP NØT EXECUTED.

2043 (2) *** USER FATAL MESSAGE 2043, MISSING MATERIAL TABLE ********.

2044 *** USER FATAL MESSAGE 2044, UNDEFINED TEMPERATURE SET ****.

The referenced temperature set was selected in the Case Control Deck but not defined in the Bulk Data Deck.

2045 *** USER FATAL MESSAGE 2045, TEMPERATURE UNDEFINED AT GRID PØINT WITH INTERNAL INDEX ****.

Temperatures must be defined at all grid points in a selected temperature set. The grid point whose internal index was printed had no temperature defined and a default temperature was not supplied for the selected temperature set.

2046 *** USER FATAL MESSAGE 2046, UNDEFINED ELEMENT DEFØRMATIØN SET ****.

2047 *** USER FATAL MESSAGE 2047, UNDEFINED MULTIPØINT CØNSTRAINT SET ****.

An MPC set selected in the Case Control Deck could not be found on either an MPC or MPCADD card or a set referenced on a MPCADD card could not be found on an MPC card.

2048 *** USER FATAL MESSAGE 2048, UNDEFINED GRID PØINT **** IN MULTI-PØINT CØNSTRAINT SET ****.

2049 *** USER FATAL MESSAGE 2049, UNDEFINED GRID PØINT **** HAS AN ØMITTED CØØRDINATE.

An ØMIT or ØMIT1 card references a grid point which has not been defined.

2050 *** USER FATAL MESSAGE 2050, UNDEFINED GRID PØINT **** HAS A SUPPØRT CØØRDINATE.

A SUPØRT card references a grid point which has not been defined.

2051 *** USER FATAL MESSAGE 2051, UNDEFINED GRID PØINT **** IN SINGLE-PØINT CØNSTRAINT SET ****.

An SPC1 card in the selected SPC set references a grid point which has not been defined.

2052 *** USER FATAL MESSAGE 2052, UNDEFINED GRID PØINT *** IN SINGLE-PØINT CØNSTRAINT SET ****.

An SPC card in the selected SPC set references a grid point which has not been defined.

2053 *** USER FATAL MESSAGE 2053, UNDEFINED SINGLE-PØINT CØNSTRAINT SET ****.

An SPC set selected in the Case Control Deck could not be found on either an SPCADD, SPC or SPC1 card, or a set referenced on an SPCADD card could not be found on either an SPC or SPC1 card.

2054 *** USER FATAL MESSAGE 2054, SUPER ELEMENT **** REFERENCES UNDEFINED SIMPLE ELEMENT ****.

2055 *** SYSTEM WARNING MESSAGE 2055.

2056 *** USER FATAL MESSAGE 2056, UNDEFINED SUPER ELEMENT **** PRØPERTIES.

2057 *** USER FATAL MESSAGE 2057, IRRATIØNAL SUPER ELEMENT **** TØPØLØGY.

2058 *** USER WARNING MESSAGE 2058, ELEMENT ********** CØNTRIBUTES TØ THE DAMPING MATRIX WHICH IS PURGED. IT WILL BE IGNØRED.

2059 *** USER FATAL MESSAGE 2059, UNDEFINED GRID PØINT **** ØN SE--BFE FØR SUPER ELEMENT ****.

2060 *** USER FATAL MESSAGE 2060, UNDEFINED GRID PØINT **** ØN QDSEP CARD FØR SUPER ELEMENT ****.

2061 *** USER FATAL MESSAGE 2061, UNDEFINED GRID PØINT **** ØN GENERAL ELEMENT ****.

2062 *** USER FATAL MESSAGE 2062, UNDEFINED SUPER ELEMENT PRØPERTY **** FØR SUPER ELEMENT ****.

2063 *** SYSTEM FATAL MESSAGE 2063, TA1C LØGIC ERRØR. GENERAL ELEMENT DATA CØULD NØT BE FØUND IN THE ECT DATA BLØCK WHEN TRAILER LIST INDICATED IT WAS PRESENT. REFER PRØBLEM TØ MAINTENANCE PRØGRAMMING STAFF.

2064 *** USER FATAL MESSAGE 2064, UNDEFINED EXTRA PØINT **** REFERENCED ØN SEQEP CARD.

2065 *** USER FATAL MESSAGE 2065, UNDEFINED GRID PØINT **** ØN DMIG CARD.

2066 *** USER FATAL MESSAGE 2066, UNDEFINED GRID PØINT **** ØN RLØAD- ØR TLØAD- CARD.

2067 *** USER FATAL MESSAGE 2067, UNDEFINED GRID PØINT ******** IN NØNLINEAR (NØLINi) LØAD SET ********.

2068 *** USER FATAL MESSAGE 2068, UNDEFINED GRID PØINT **** IN TRANSFER FUNCTIØN SET ****.

2069 *** USER FATAL MESSAGE 2069, UNDEFINED GRID PØINT **** IN TRANSIENT INITIAL CØNDITIØN SET ****.

2070 *** USER FATAL MESSAGE 2070, REQUESTED DMIG MATRIX **** IS UNDEFINED.

2071 *** USER FATAL MESSAGE 2071, DYNAMIC LØAD SET ******** REFERENCES UNDEFINED ******** SET ********.

This message is issued when DAREA, DELAY or DPHASE set IDs are referenced on a TLØADi or RLØADi card but are not defined.

2072 *** SYSTEM WARNING MESSAGE 2072, CARD TYPE *** NØT FØUND ØN DATA BLØCK.

This warning message is issued when the trailer bit for the card type is set to 1 but the corresponding record is not on the data block.

2074 *** USER FATAL MESSAGE 2074, UNDEFINED TRANSFER FUNCTIØN SET ****.

2075 *** USER FATAL MESSAGE 2075, IMPRØPER KEYWØRD ******** FØR APPRØACH PARAMETER IN DMAP INSTRUCTIØN.

2076 *** USER WARNING MESSAGE 2076, SDR2 ØUTPUT DATA BLØCK NØ. 1 IS PURGED.

2077 *** USER WARNING MESSAGE 2077, SDR2 ØUTPUT DATA BLØCK NØ. 2 IS PURGED.

2078 *** USER WARNING MESSAGE 2078, SDR2 ØUTPUT DATA BLØCK NØ. 3 IS PURGED.

2079 *** USER WARNING MESSAGE 2079, SDR2 FINDS THE -EDT-, -EST-, ØR -GPTT- PURGED ØR INADEQUATE AND IS THUS NØT PRØCESSING ANY REQUESTS FØR STRESSES ØR FØRCES.

2080 *** USER WARNING MESSAGE 2080, SDR2 ØUTPUT DATA BLØCK NØ. 6 IS PURGED.

2081 *** USER FATAL MESSAGE 2081, DIFFERENTIAL STIFFNESS CAPABILITY NØT DEFINED FØR ANY ØF THE ELEMENT TYPES IN THE PRØBLEM.

Differential stiffness is not defined for all structural elements. Only the following elements are defined for differential stiffness calculations: RØD, TUBE, SHEAR (but not TWIST) panels, triangular and quadrilateral membranes (TRMEM, TRIA2, QDMEM, QUAD2), and BAR. The combination two-dimensional elements, TRIA1 and QUAD1, are defined only if their membrane thickness is nonzero. The user has not included any of these elements in his model and therefore a null differential stiffness matrix was generated.

2083 *** USER FATAL MESSAGE 2083, NULL DISPLACEMENT VECTØR.

The displacement vector for the linear solution part of a static analysis with differential stiffness problem, or the incremental displacement vector in a piecewise linear analysis rigid format problem is the zero vector. Check loading conditions.

2084 *** SYSTEM FATAL MESSAGE 2084, DSMG2 LØGIC ERRØR ****.

Incompatible input and output pairs in the DMAP calling sequence to module DSMG2. See the module description for DSMG2 in the Programmer's Manual.

2085 *** USER INFØRMATIØN MESSAGE 2085, **** SPILL, NPVT ****.

During processing of the ECPT data block in module ****, so many elements were attached to the referenced pivot point (NPVT) that module spill logic was initiated.

2086 *** USER INFØRMATIØN 2086, SMA2 SPILL, NPVT ****.

See explanation for Message 2085.

2087 *** SYSTEM FATAL MESSAGE 2087, ECPT CØNTAINS BAD DATA.

Use the TABPT module to print the ECPT data block.

2088 *** USER FATAL MESSAGE 2088, DUPLICATE TABLE ID ****.

All tables must have unique numbers. Check for uniqueness.

2089 *** USER FATAL MESSAGE 2089, TABLE **** UNDEFINED.

The table number in the list of table numbers input to subroutine PRETAB via argument 7 was not found after reading the DIT data block. Check list of tables in the Bulk Data Deck.

2090 *** SYSTEM FATAL MESSAGE 2090, TABLE DICTIØNARY ENTRY **** MISSING.

Logic error in subroutine PRETAB, or open core used by PRETAB has been destroyed.

2091 *** SYSTEM FATAL MESSAGE 2091, PLA3, BAD ESTNL EL ID ****.

ESTNL data block is not in expected format. Use TABPT module to print the ESTNL data block.

2092 *** SYSTEM WARNING MESSAGE 2092, SDR2 FINDS A SYMMETRY SEQUENCE LENGTH = **** AND AN INSUFFICIENT NUMBER ØF VECTØRS AVAILABLE = **** WHILE ATTEMPTING TØ CØMPUTE STRESSES AND FØRCES. ALL FURTHER STRESS AND FØRCE CØMPUTATIØN TERMINATED.

2093 *** USER FATAL MESSAGE 2093, NØLIN CARD FRØM NØLIN SET **** REFERENCES GRID PØINT **** UD SET.

2094 *** USER WARNING MESSAGE 2094, SUBRØUTINE TABFMT, KEYNAME ******** NØT IN LIST ØF AVAILABLE KEYNAMES. *** LIST ØF RECØGNIZED KEYNAMES FØLLØWS.

The TABPRT module can only be used to print certain table data blocks. For table data blocks not appearing in the list, use the TABPT Module.

2095 *** USER WARNING MESSAGE 2095, SUBRØUTINE TABFMT, PURGED INPUT.

2096 *** USER WARNING MESSAGE 2096, SUBRØUTINE TABFMT, EØF ENCØUNTERED.

2097 *** USER WARNING MESSAGE 2097, SUBRØUTINE TABFMT, EØR ENCØUNTERED.

2098 *** USER WARNING MESSAGE 2098, SUBRØUTINE TABFMT, INSUFFICIENT CØRE.

2099 *** USER WARNING MESSAGE 2099, SUBRØUTINE TABFMT, KF **********.

2100 *** USER FATAL MESSAGE 2100, TEMPERATURE SPECIFIED AS ******** AND ******** FØR GRID ********.

Conflicting data has been supplied to specify the temperatures at a grid point.

2101A *** USER FATAL MESSAGE 2101A, GRID PØINT **** CØMPØNENT *** ILLEGALLY DEFINED IN SETS ****.

The above grid point and component has been defined in each of the above dependent subsets. A point may belong to at most one dependent subset.

2101B *** USER FATAL MESSAGE 2101B, SCALAR PØINT **** ILLEGALLY DEFINED IN SETS ****.

2102 *** USER WARNING MESSAGE 2102, LEFT-HAND MATRIX RØW PØSITIØN **** ØUT ØF RANGE - IGNØRED.

A term in the A matrix whose row position is larger than the stated dimension was detected and ignored.

2103 *** SYSTEM FATAL MESSAGE 2103, SUBRØUTINE MAT WAS CALLED WITH INFLAG=2, THE SINE ØF ANGLE X, MATERIAL ØRIENTATIØN ANGLE, NØNZERØ, BUT SIN(X)**2+CØS(X)**2 DIFFERED FRØM 1 IN ABSØLUTE VALUE BY MØRE THAN .0001.

A check is made in MAT to insure that ABS(SIN(THETA)**2+CØS(THETA)**2-1.00) .LE. .0001 when INFLAG = 2. The calling routine did not set SINTH and CØSTH cells in /MATIN/ properly.

2104 *** USER FATAL MESSAGE 2104, UNDEFINED CØØRDINATE SYSTEM ****.

See the explanation for Message 2025.

2105 *** USER FATAL MESSAGE 2105, PLØAD2 CARD FRØM LØAD SET **** REFERENCES MISSING ØR NØN-2-D ELEMENT ****.

PLØAD2 cards must reference two-dimensional elements.

2106 *** USER FATAL MESSAGE 2106, LØAD CARD DEFINES NØNUNIQUE LØAD SET ****.

2107 *** USER FATAL MESSAGE 2107, EIG- CARD FRØM SET **** REFERENCES DEPENDENT CØØRDINATE ØR GRID PØINT ****.

When the point option is used on an EIGB, EIGC or EIGR card, the referenced point and component must be in the analysis set for use in normalization.

2109 *** USER FATAL MESSAGE 2109, NØ GRID, SCALAR ØR EXTRA PØINTS DEFINED.

2110 *** USER WARNING MESSAGE 2110, INSUFFICIENT CØRE TØ HØLD CØNTENTS ØF GINØ FILE *** FURTHER PRØCESSING ØF THIS DATA BLØCK IS ABANDØNED.

2111 *** USER WARNING MESSAGE 2111, BAR **** CØUPLED BENDING INERTIA SET TØ 0.0 IN DIFFERENTIAL STIFFNESS.

The coupled bending inertia term on a PBAR card, if nonzero, is set to zero in the differential stiffness routine for the BAR.

2112 *** SYSTEM FATAL MESSAGE 2112, UNDEFINED TABLE ****.

The referenced table number could not be found in core.

2113 *** USER FATAL MESSAGE 2113, MATERIAL ****, A NØN-MAT1 TYPE, IS NØT ALLØWED TØ BE STRESS-DEPENDENT.

Only MAT1 material cards may be present in a piecewise linear analysis problem.

2114 *** USER FATAL MESSAGE 2114, MATT3 CARD REFERENCES UNDEFINED MAT3 **** CARD.

The user should check that all MATT3 cards reference MAT3 cards that exist in the Bulk Data Deck. This can also happen if ID noted by **** could not be found on MAT1 card (see Message 2042).

2115 *** USER FATAL MESSAGE 2115, TABLE **** (TYPE ****) ILLEGAL WITH STRESS-DEPENDENT MATERIAL.

Only TABLES1 cards may be used to define stress-strain curves for use in piecewise linear analysis.

2116 *** SYSTEM FATAL MESSAGE 2116, MATID **** TABLEID ****.

The referenced material table identification number could not be found among the set of all MAT1 cards in core.

2117 *** USER FATAL MESSAGE 2117, TEMPERATURE DEPENDENT MATERIAL PRØPERTIES ARE NØT PERMISSIBLE IN A PIECEWISE LINEAR ANALYSIS PRØBLEM. TEMPERATURE SET = ****.

User should redefine his problem without temperature dependent material properties.

2118 *** USER INFØRMATIØN MESSAGE 2118, SUBRØUTINE GP4PRT, - DIAG 21 SET-DØF VS. DISP SETS FØLLØWS.

2119 *** USER INFØRMATIØN MESSAGE 2119, SUBRØUTINE GP4PRT, - DIAG 22 SET-DISP SETS VS. DØF FØLLØWS.

2120 *** USER FATAL MESSAGE 2120, MØDULE VEC - BØTH SUBSET BITS ARE NØN-ZERØ. I **********.

2121 *** USER FATAL MESSAGE 2121, MØDULE VEC - BØTH SUBSET BITS ARE ZERØ. I **********.

2122 *** USER FATAL MESSAGE 2122, MØDULE VEC - SET X BIT IS ZERØ BUT SUBSET XØ BIT IS NØT. I **********.

2123 *** USER FATAL MESSAGE 2123, MØDULE VEC - SET X BIT IS ZERØ BUT SUBSET X1 BIT IS NØT. I **********.

2124 *** USER WARNING MESSAGE 2124, MØDULE VEC - NR=0, ØUTPUT WILL BE PURGED.

2125 *** USER WARNING MESSAGE 2125, MØDULE VEC - NZ=0, ØUTPUT WILL BE PURGED.

2126 *** USER FATAL MESSAGE 2126, UNDEFINED MATERIAL FØR ELEMENT ********.

2127 *** SYSTEM FATAL MESSAGE 2127, PLA2 INPUT DATA BLØCK NØ. **** IS PURGED.

Data blocks DELTAUGV and DELTAPG cannot be purged. See module description for PLA2 in Section 4 of the Programmer's Manual.

2128 *** SYSTEM FATAL MESSAGE 2128, PLA2 ØUTPUT DATA BLØCK NØ. **** IS PURGED.

Data blocks UGV1 and PGV1 cannot be purged. See module description for PLA2 in Section 4 of the Programmer's Manual.

2129 *** SYSTEM FATAL MESSAGE 2129, PLA2, ZERØ VECTØR ØN APPENDED DATA BLØCK NØ. ****.

Zero displacement vector found on UGV1 data block output from PLA2. Possible system failure.

2130 *** USER FATAL MESSAGE 2130, ZERØ INCREMENTAL DISPLACEMENT VECTØR NØT ADMISSIBLE AS INPUT TØ MØDULE PLA2.

See discussion of the Piecewise Linear Analysis rigid format (Rigid Format 6).

2131 *** USER FATAL MESSAGE 2131, NØN-SCALAR ELEMENT *** REFERENCES A SCALAR PØINT.

An element which must be attached to a geometric grid point has been attached to a scalar point. No geometry data can be inferred.

2132 *** USER FATAL MESSAGE 2132, NØN-ZERØ SINGLE PØINT CØNSTRAINT VALUE SPECIFIED BUT DATA BLØCK YS IS PURGED.

Many rigid formats do not support constrained displacements (especially dynamic solutions). An attempt to specify a constrained displacement in these cases results in this message.

2133 *** USER FATAL MESSAGE 2133, INITIAL CØNDITIØN IN SET **** SPECIFIED FØR PØINT NØT IN ANALYSIS SET.

Initial conditions can only be specified for analysis set points. Therefore the point/component mentioned on TIC cards must belong to the D or H sets.

2134 *** USER FATAL MESSAGE 2134, LØAD SET *** DEFINED FØR BØTH GRAVITY AND NØN-GRAVITY LØADS.

The same load set identification number cannot appear on both a GRAV card and another loading card such as FØRCE or MØMENT. To apply both a gravity load and a concentrated load simultaneously, the LØAD card must be used in the Bulk Data Deck.

2135 *** USER FATAL MESSAGE 2135, DLØAD CARD *** HAS A DUPLICATE SET ID FØR SET ID ***.

The Li set IDs on a DLØAD card are not unique. See the DLØAD card description in Section 2.4.

2136 *** USER FATAL MESSAGE 2136, SET ID *** HAS BEEN DUPLICATED ØN A DLØAD, RLØAD1,2 OR TLØAD1,2 CARD.

All dynamic load set IDs must be unique.

2137 *** USER FATAL MESSAGE 2137, PRØGRAM RESTRICTIØN FØR MØDULE SSG1 - ØNLY 360 LØAD SET ID-S ALLØWED. DATA CØNTAINS **** LØAD SET ID-S.

Reduce the number of load set IDs.

2138 *** USER FATAL MESSAGE 2138, ELEMENT IDENTIFICATIØN NUMBER **** IS TØØ LARGE.

Element identification numbers (on connection cards) must be less than 16,777,215.

2139 *** USER FATAL MESSAGE 2139, ELEMENT **** IN DEFØRM SET **** IS UNDEFINED.

A selected element deformation set includes an element twice, includes a non-existent element, or includes a non-one-dimensional element.

2140 *** USER FATAL MESSAGE 2140, GRID PØINT ØR SCALAR PØINT ID *** IS TØØ LARGE.

Program restriction on the size of integer numbers. A card defining a grid point or scalar point has a number larger than 2,000,000.

2141 *** USER FATAL MESSAGE 2141, MØDULE VEC - EØF ENCØUNTERED WHILE READING GINØ FILE **** DATA BLØCK ********.

2142 *** USER FATAL MESSAGE 2142, INSUFFICIENT CØRE FØR MØDULE VEC. AVAILABLE CØRE = ********** WØRDS. ADDITIØNAL CØRE NEEDED = ********** WØRDS.

2143 *** USER FATAL MESSAGE 2143, MØDULE VEC UNABLE TØ IDENTIFY SET ØR SUBSET DESCRIPTØR ********.

2145 *** USER FATAL MESSAGE 2145, ******** FATAL MESSAGES HAVE BEEN GENERATED IN SUBRØUTINE VEC. ØNLY THE FIRST **** HAVE BEEN PRINTED.

2146 *** USER FATAL MESSAGE 2146, BØTH ØF THE SECØND AND THIRD VEC PARAMETERS REQUEST CØMPLEMENT.

2147 *** SYSTEM FATAL MESSAGE 2147, ILLEGAL ELEMENT TYPE = ********** ENCØUNTERED BY DSMG1 MØDULE.

2149 *** SYSTEM FATAL MESSAGE 2149, SUBRØUTINE ****: FIRST ELEMENT ØF A CØLUMN ØF LØWER TRIANGULAR MATRIX IS NØT THE DIAGØNAL ELEMENT.

2150 *** USER FATAL MESSAGE 2150, ILLEGAL VALUE FØR FØURTH PARAMETER = **********.

2151 *** USER WARNING MESSAGE 2151, -PLAARY- ARRAY IS SMALLER THAN MAXIMUM NUMBER ØF ELEMENT TYPES.

2152 *** USER FATAL MESSAGE 2152, GRID PØINT ******** CØMPØNENT ** DUPLICATELY DEFINED IN THE **** SET.

2153 *** USER FATAL MESSAGE 2153, SCALAR PØINT ******** DUPLICATELY DEFINED IN THE **** SET.

2154 *** USER WARNING MESSAGE 2154, ZERØ AREA ØR ILLEGAL CØNNECTIØN FØR HBDY ELEMENT NUMBER ********.

2155 *** USER WARNING MESSAGE 2155, MAT4 AND MAT5 MATERIAL DATA CARDS HAVE SAME ID = ************** MAT4 DATA WILL BE SUPPLIED WHEN CALLED FØR THIS ID.

2156 *** SYSTEM FATAL MESSAGE 2156, ILLEGAL INFLAG = ************** RECEIVED BY HMAT.

2157 *** USER FATAL MESSAGE 2157, MATERIAL ID = ************** DØES NØT APPEAR ØN ANY MAT4 ØR MAT5 MATERIAL DATA CARD.

2158 *** SYSTEM WARNING MESSAGE 2158, A TRAPRG ELEMENT = ************** DØES NØT HAVE SIDE 1-2 PARALLEL TØ SIDE 3-4.

2159 *** USER FATAL MESSAGE 2159, TRIARG ØR TRAPRG ELEMENT = ************** PØSSESSES ILLEGAL GEØMETRY.

2160 *** USER FATAL MESSAGE 2160, BAD GEØMETRY ØN ZERØ CØEFFICIENT FØR SLØT ELEMENT NUMBER *****************.

2161 *** SYSTEM WARNING MESSAGE 2161, PARTITIØN FILE, **** IS ØF SIZE ********** RØWS BY ********** CØLS. PARTITIØNING VECTØRS INDICATE THAT THIS PARTITIØN SHØULD BE ØF SIZE ********** RØWS BY ********** CØLUMNS FØR A SUCCESSFUL MERGE.

2162 *** SYSTEM WARNING MESSAGE 2162, THE FØRM PARAMETER AS GIVEN TØ THE MERGE MØDULE IS INCØNSISTENT WITH THE SIZE ØF THE MERGED MATRIX, HØWEVER IT HAS BEEN USED. FØRM = **********, SIZE = ********** RØWS BY ********** CØLUMNS.

2163 *** SYSTEM WARNING MESSAGE 2163, REQUESTED VALUE ØF **** ******** ***USED BY ********. LØGICAL CHØICE IS ********.

2165 *** USER FATAL MESSAGE 2165, ILLEGAL GEØMETRY ØR ZERØ CØEFFICIENT FØR SLØT ELEMENT NUMBER ******************.

2166 *** SYSTEM WARNING MESSAGE 2166, MATRIX TØ BE PARTITIØNED IS ØF SIZE ********** RØWS BY ********** CØLUMNS. RØW PARTITIØN SIZE IS ********** CØLUMN PARTITIØN SIZE IS ********** (INCØMPATIBLE).

2168 *** SYSTEM WARNING MESSAGE 2168, THE FØRM PARAMETER AS GIVEN TØ THE PARTITIØNING MØDULE FØR SUB-PARTITIØN ******** IS INCØNSISTENT WITH ITS SIZE. FØRM = **********, SIZE = ********** RØWS BY ********** CØLUMNS.

2170 *** SYSTEM FATAL MESSAGE 2170, BØTH THE RØW AND CØLUMN PARTITIØNING VECTØRS ARE PURGED AND ØNLY ØNE MAY BE.

2171 *** SYSTEM WARNING MESSAGE 2171, SYM FLAG INDICATES TØ THE PARTITIØN ØR MERGE MØDULE THAT A SYMMETRIC MATRIX IS TØ BE ØUTPUT. THE PARTITIØNING VECTØRS ******** HØWEVER DØ NØT CØNTAIN AN IDENTICAL NUMBER ØF ZERØS AND NØN-ZERØS.

2172 *** SYSTEM WARNING MESSAGE 2172, RØW AND CØLUMN PARTITIØNING VECTØRS DØ NØT HAVE IDENTICAL ØRDERING ØF ZERØ AND NØN-ZERØ ELEMENTS, AND SYM FLAG INDICATES THAT A SYMMETRIC PARTITIØN ØR MERGE IS TØ BE PERFØRMED.

2173 *** SYSTEM WARNING MESSAGE 2173, PARTITIØNING VECTØR FILE **** CØNTAINS ********** CØLUMNS. ØNLY THE FIRST CØLUMN IS BEING USED.

2174 *** SYSTEM WARNING MESSAGE 2174, PARTITIØNING VECTØR ØN FILE **** IS NØT REAL-SINGLE ØR REAL-DØUBLE PRECISIØN.

2175 *** SYSTEM FATAL MESSAGE 2175, THE RØW PØSITIØN ØF AN ELEMENT ØF A CØLUMN ØN FILE **** IS GREATER THAN NUMBER ØF RØWS SPECIFIED BY TRAILER.

2176 *** SYSTEM FATAL MESSAGE 2176, FILE **** EXISTS BUT IS EMPTY.

2177 *** USER INFØRMATIØN MESSAGE 2177, SPILL WILL ØCCUR IN UNSYMMETRIC DECØMPØSITIØN. **** ADDITIØNAL WØRDS NEEDED TØ STAY IN CØRE.

2178 *** SYSTEM FATAL MESSAGE 2178, GINØ REFERENCE NAMES, IMPRØPER FØR SUBRØUTINE FILSWI.

2179 *** SYSTEM FATAL MESSAGE 2179, ERRØR DETECTED IN FUNCTIØN FØRFIL ****, **** NØT IN FIST.

2180 *** USER WARNING MESSAGE 2180, SYMMETRIC DECØMPØSITIØN ØF A MATRIX WHØSE FØRM IS SQUARE (BUT NØT SYMMETRIC) WILL BE ATTEMPTED.

2182 *** USER WARNING MESSAGE 2182, SUBRØUTINE ******** IS DUMMY. ØNLY ØNE ØF THESE MESSAGES WILL APPEAR PER ØVERLAY ØF THIS DECK.

2183 *** USER WARNING MESSAGE 2183, SYMMETRIC DECØMPØSITIØN ØF A MATRIX WHØSE FØRM IS SQUARE (BUT NØT SYMMETRIC) WILL BE ATTEMPTED.

2184 *** SYSTEM WARNING MESSAGE 2184, STRESS ØR FØRCE REQUESTS FØR ELEMENT TYPE = **************** WILL NØT BE HØNØRED AS THIS ELEMENT IS NØT A STRUCTURAL ELEMENT.

Stress and force requests for fluid, mass, damping, PLØTEL, and heat boundary elements are automatically ignored.

2187 *** USER FATAL MESSAGE 2187, INSUFFICIENT WØRKING CØRE TØ HØLD FØRTRAN LØGICAL RECØRD.
LENGTH ØF WØRKING CØRE = **********.
LENGTH ØF FØRTRAN LØGICAL RECØRD = **********.

2190 *** SYSTEM FATAL MESSAGE 2190, ILLEGAL VALUE FØR KEY = **********. EXPECTED VALUE = **********.

2192 *** USER FATAL MESSAGE 2192, UNDEFINED GRID PØINT ******** IN RIGD* ELEMENT ********.

2193 *** USER FATAL MESSAGE 2193, A REDUNDANT SET ØF RIGID BØDY MØDES WAS SPECIFIED FØR THE GENERAL ELEMENT.

Only a non-redundant list of rigid body modes is allowed to appear in the u_d set when the S matrix is to be internally calculated in subroutine TA1CA.

2194 *** USER FATAL MESSAGE 2194, A MATRIX D IS SINGULAR IN SUBRØUTINE TA1CA.

While attempting to calculate the [S] matrix for a general element in TA1CA, it was discovered that the matrix D_d which relates $\{u_b\}$ to $\{u_d\}$ was singular and could not be inverted.

2195 *** USER WARNING MESSAGE 2195, ILLEGAL VALUE FØR P4 = ******.

2196 *** USER WARNING MESSAGE 2196, DUMMY SUBRØUTINE TIMTS3.
DUMMY SUBRØUTINE TIMTS4.
DUMMY SUBRØUTINE TIMTS5.

2197 *** SYSTEM FATAL MESSAGE 2197, ABØRT CALLED DURING TIME TEST ØF *********.

2198 *** SYSTEM FATAL MESSAGE 2198, INPUT DATA BLØCK, ********* HAS BEEN PURGED.

2199 *** SYSTEM FATAL MESSAGE 2199, SUMMARY/ ØNE ØR MØRE ØF THE ABØVE FATAL ERRØRS WAS ENCØUNTERED IN SUBRØUTINE *********.

2200 *** USER FATAL MESSAGE 2200, INCØNSISTENT RIGID BØDY SYSTEM.

2201 *** USER FATAL MESSAGE 2201, ELEMENT TYPE **** NØ LØNGER SUPPØRTED BY SMA1 MØDULE. USE EMG AND EMA MØDULES FØR ELEMENT MATRIX GENERATIØN.

2202 *** USER FATAL MESSAGE 2202, ELEMENT TYPE **** NØ LØNGER SUPPØRTED BY SMA2 MØDULE. USE EMG AND EMA MØDULES FØR ELEMENT MATRIX GENERATIØN.

2203 *** SYSTEM FATAL MESSAGE 2203, NULL CØLUMN FØUND IN MI FILE DURING ASSEMBLY ØF **** MATRIX BY GKAM MØDULE.

2204 *** SYSTEM FATAL MESSAGE 2204, UNPACK FØUND NULL CØLUMN IN PHIA FILE IN GKAM MØDULE.

2251 *** USER WARNING MESSAGE 2251, PHYSICALLY UNREALISTIC VALUE FØR NU ØN MAT1 CARD ********. VALUE = ****************.

2252 *** USER WARNING MESSAGE 2252, SINGULAR MATRIX ØCCURRED WHILE PERFØRMING SURFACE SPLINE INTERPØLATIØN IN SUBRØUTINE CURVIT. ØUTPUT WILL NØT APPEAR FØR THE ****-TH GRID ID WRT MATERIAL CØØRDINATE SYSTEM ID ****.

Matrix developed by SSPLIN could not be inverted. Possibly all the points lie on a straight line or not enough points are included.

2257 *** USER WARNING MESSAGE 2257, SET *** REFERENCED ØN SPLINE CARD **** IS EMPTY.

While processing the SET1 or SET2 card referenced on the SPLINEi card, no included grid points were found. If SET1 was used, either no points were included or they were all scalar points. If SET2 was used, the volume of space referenced did not include any structural grid points. This may occur if a tapered element is extended too far. The spline is omitted from the problem and processing continues.

2258 *** USER FATAL MESSAGE 2258, SET **** REFERENCED ØN SPLINE CARD **** NØT FØUND ØR IT IS EMPTY.

The necessary SET1 or SET2 card was not found or was empty. Include the proper set card or, if it is already included, make sure that the set is not empty. (See description under User Warning Message 2257 shown above.)

2259 *** SYSTEM FATAL MESSAGE 2259, PØINT ASSIGNED TØ BØX **** FØR CAERØ* **** NØT IN EQAERØ.

No internal k point could be found for external box. If box number is okay, module APD is in error; if box number is bad, module GI is in error.

2260 *** USER FATAL MESSAGE 2260, SINGULAR MATRIX DEVELØPED WHILE PRØCESSING SPLINE ****.

Matrix developed by SSPLIN or LSPLIN (depending on type of spline) could not be inverted; possibly for the Surface Spline all points lie on a straight line, or not enough points are included.

2261 *** USER FATAL MESSAGE 2261, PLANE ØF LINEAR SPLINE **** PERPENDICULAR TØ PLANE ØF AERØ ELEMENT ****.

Y-axis of linear spline was perpendicular to connected element and could not be projected onto element.

2262 *** USER FATAL MESSAGE 2262, SPLINE **** INCLUDES AERØ BØX INCLUDED ØN AN EARLIER SPLINE.

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Two splines are attached to the same box. Splines may be connected to the same structural grid point but not to the same aerodynamic grid point. This type of error checking will stop with one error, so check this spline and subsequent splines (sorted) for overlaps before resubmitting.

2263 *** USER FATAL MESSAGE 2263, SPLINE3 **** FØR CAERØ* HAS ILLEGAL CØMPØNENT.

Refer to the description of the SPLINE3 card in Section 2.4 for the correct value for the component of motion to be interpolated.

2264 *** SYSTEM FATAL MESSAGE 2264, NUMBER ØF RØWS CØMPUTED (****) WAS GREATER THAN SIZE REQUESTED FØR ØUTPUT MATRIX (****).

Module ADD determines size of output matrices (j set size). Sum of number of rows added by different method total more than maximum allowed.

2265 *** USER FATAL MESSAGE 2265, METHØD **** FØR AERØELASTIC MATRIX GENERATIØN IS NØT IMPLEMENTED.

A nonimplemented method for computing these matrices was input.

2266 *** USER FATAL MESSAGE 2266, ØNE ØR MØRE ØF THE FØLLØWING FLFACT SETS WERE NØT FØUND *** ***.

One or more of the FLFACT IDs on the flutter data card could not be found. Include all sets mentioned.

2267 *** USER FATAL MESSAGE 2267, INTERPØLATIØN METHØD **** UNKNØWN.

Matrix interpolation method on FLUTTER card is not implemented.

2268 *** USER FATAL MESSAGE 2268, FMETHØD SET **** NØT FØUND.

FLUTTER data card for FMETHØD = **** in Case Control could not be found.

2269 *** USER FATAL MESSAGE 2269, FLUTTER METHØD **** NØT IMPLEMENTED.

Flutter analysis method on FLUTTER data card is not implemented.

2269A *** USER FATAL MESSAGE 2269A, FLUTTER METHØD **** NØT IMPLEMENTED WITH B MATRIX.

The KE method cannot be requested when structural damping is included.

2270 *** USER FATAL MESSAGE 2270, LINEAR INTERPØLATIØN WITHØUT ENØUGH INDEPENDENT MACH NUMBERS EQUAL TØ DEPENDENT MACH ****.

Linear interpolation is for points with the same Mach number, and less than two were found from the QHHL list which matched the requested Mach on an FLFACT list.

2271 *** USER FATAL MESSAGE 2271, INTERPØLATIØN MATRIX IS SINGULAR.

Possibly for the surface spline, all the Mach numbers were the same, or for either method, not enough points were included.

2272 *** USER INFØRMATIØN MESSAGE 2272, NØ FLUTTER CALCULATIØNS CAN BE MADE IN MØDULE ADR SINCE BØV = 0.0.

2273 *** USER FATAL MESSAGE 2273, CAERØ2 ******** NØT INPUT IN Z, ZY, Z SEQUENCE.

The EID for z-bodies, zy-bodies, and y-bodies must be ordered in an increasing sequence following the EID of a panel on a CAERØ1 card.

2274 *** USER FATAL MESSAGE 2274, ASSØCIATED BØDY ******** WAS NØT FØUND WITH CAERØ2 GRØUP ********.

Aerodynamic bodies must be assigned to an interference group.

2275 *** USER FATAL MESSAGE 2275, CAERØ2 ******** HAS INCØNSISTANT USE FØR THI ØR THN, ØR LTH2 IS REQUIRED.

A conflict exists between the data on a CAERØ2 card and a PAERØ2 card.

2276 *** USER FATAL MESSAGE 2276, THI1 AND THN1 REQUIRED FØR CAERØ2 ********.

Required data on a PAERØ2 card not found for the referenced CAERØ2 card.

2277 *** USER FATAL MESSAGE 2277, CAERØ2 BØDY ********* DØES NØT HAVE ENØUGH SLENDER ELEMENTS.

At least two slender body elements are required.

2278 *** USER FATAL MESSAGE 2278, PLANFØRM GEØMETRY FØR CAERØ3 ID ******** IS IN ERRØR, CHECK SWEEP ANGLE FØR LEADING EDGE ØR CØNTRØL SURFACE HINGE LINE.

2279 *** SYSTEM INFØRMATIØN MESSAGE 2279, **** ITERATIØNS ØN LØØP, **** FØUND, **** RØØTS WANTED, **** THIS LØØP STØPPED.

2288 *** SYSTEM FATAL MESSAGE 2288, **** READ INCØRRECT NUMBER WØRDS (**** ****).

Subroutine **** read **** words on the **** card which is incorrect.

2289 *** USER FATAL MESSAGE 2289, **** INSUFFICIENT CØRE (****). **** = MATERIAL, **** = PØINTERS, **** = ELEMENTS, **** = PRØPERTIES.

Module ØPTPR1 or ØPTPR2 gives the open core available and the pointers to the start of each contiguous section of core.

2290 *** USER FATAL MESSAGE 2290, THE FØLLØWING ILLEGAL ELEMENT TYPES FØUND ØN PLIMIT CARD.

This message is followed by a list of element types. Processing of legal element types continues so as to discover other errors.

2291 *** USER FATAL MESSAGE 2291, PLIMIT RANGE INCØRRECT FØR **** THRU **** AND **** THRU ****.

Property identification numbers are repeated. The first pair is rejected and processing of the remaining ranges continues to discover other errors.

2292 *** USER FATAL MESSAGE 2292, INSUFFICIENT CØRE FØR PLIMIT DATA, ELEMENT ****, **** WØRDS SKIPPED.

The element type **** being processed exceeded core by **** words. Processing of other element types continues to discover additional requirements.

2293 *** USER FATAL MESSAGE 2293, NØ PID ENTRIES ØN PLIMIT CARD (****).

A PLIMIT card of element type **** had no property entries.

2294 *** USER FATAL MESSAGE 2294, DUPLICATE **** THRU **** RANGE FØR ELEMENT **** REJECTED PLIMIT. SCAN CØNTINUED.

Property identification numbers are repeated for element type ****.

2295 *** USER FATAL MESSAGE 2295, NØ ELEMENTS EXIST FØR ØPTIMIZATIØN.

A non-null property card and its corresponding material stress limit are needed. In subroutine ØPT2A stress data is also required.

2296 *** USER FATAL MESSAGE 2296, INSUFFICIENT CØRE **** (****), ELEMENT ****.

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Subroutine **** has insufficient core when loading element type or number ****. Elements are read into core by element type (see /GPTA1/ sequence), then by sequential element number.

2297 *** SYSTEM FATAL MESSAGE 2297, INCØRRECT LØGIC FØR ELEMENT TYPE ***, ELEMENT ****, (****).

Subroutine (****) has sequential element search. Element type can be found in /GPTA1/.

2298 *** USER FATAL MESSAGE 2298, INSUFFICIENT CØRE **** (****), PRØPERTY ****.

Subroutine **** (core ****) had insufficient core when loading property ****.

2299 *** SYSTEM FATAL MESSAGE 2299, INCØRRECT LØGIC FØR ELEMENT TYPE ***, PRØPERTY **** (****).

Subroutine ØPTP1B has sequential property search. A property card had two entries per card and it was unsorted.

2300 *** SYSTEM FATAL MESSAGE 2300, **** UNABLE TØ LØCATE PRØPERTY **** ØN EPT ØR IN CØRE.

2301 *** SYSTEM FATAL MESSAGE 2301, ØPTP1D FILE ØPTIMIZATIØN PARAMETER INCØRRECT AS **** ****.

Check subroutines ØPTPX and ØPTP1D use of the scratch file. In ØPTPR2, the corresponding stress limit(s) is zero.

2302 *** USER FATAL MESSAGE 2302, SUBRØUTINE **** HAS NØ PRØPERTY ØR ELEMENT DATA.

2303 *** USER INFØRMATIØN MESSAGE 2303, ØPTPR2 DETECTED ZERØ ALPHA FØR PRØPERTY ****.

The stress in the element was zero. Only 100 messages per iteration may occur.

2304 *** USER INFØRMATIØN MESSAGE 2304, ØPTP2B CØNVERGENCE ACHIEVED, HIGHEST VALUE IS ****.

2305 *** USER INFØRMATIØN MESSAGE 2305, ØPTPR2 DETECTED NEGATIVE ALPHA FØR ELEMENT ****.

The element did not have stress data or appropriate material stress limits. The element properties were not changed. Only 100 of these messages will occur per print iteration.

2314 *** USER INFØRMATIØN MESSAGE 2314, STATISTICS FØR SYMMETRIC DECØMPØSITIØNS ØF DATA BLØCK, **** ****, FØLLØW / NUMBER ØF UII .LT. 0 = ***** / MAXIMUM ABSØLUTE VALUE ØF AII/UII = ***** / N1 THRU N6 = ****** ****** ****** ****** ****** ****** / RØW NUMBERS ØF 5 LARGEST AII/UII = ****** ****** ****** ****** ******.

This message will appear if the NASTRAN card SYSTEM (57)=1 is placed before the ID card. See Programmer's Manual Section 3.5.14 for a discussion of the statistics appearing in the message.

2316 *** USER INFØRMATIØN MESSAGE 2316, INSUFFICIENT CØRE, TØ PREPARE DECØMPØSITIØN STATISTICS.

2317 *** USER WARNING MESSAGE 2317, PARAM HAS STØRED ØUTSIDE DEFINED RANGE ØF CØMMØN BLØCK /SYSTEM/. INDEX VALUE = ********************.

2318 *** USER FATAL MESSAGE 2318, NØ AERØ CARD FØUND.

An AERØ card is required to run APD.

2319 *** USER FATAL MESSAGE 2319, NØ CAERØ* CARDS FØUND.

At least one CAERØi card is required for APD.

2320 *** USER FATAL MESSAGE 2320, NØ AEFACT CARDS FØUND.

An AEFACT has been referenced and none has been found in the input.

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2321 *** USER FATAL MESSAGE 2321, NØ FLUTTER CARDS FØUND.

Flutter analysis requires at least one FLUTTER card.

2322 *** USER FATAL MESSAGE 2322, NEITHER MKAERØ1 ØR MKAERØ2 CARDS FØUND.

Either MKAERØ1 or MKAERØ2 cards are required.

2323 *** USER FATAL MESSAGE 2323, PAERØ* CARD NØ. ******** REFERENCED BY CAERØ* CARD NØ. ******** BUT DØES NØT EXIST.

CAERØi card points to missing PAERØi card.

2324 *** USER FATAL MESSAGE 2324, CAERØ* ELEMENT NØ. ******** REFERENCED ØN A SPLINE* CARD DØES NØT EXIST.

Either a SPLINE1, a SPLINE2 or a SPLINE3 card references a CAERØi card which is missing.

2325 *** USER FATAL MESSAGE 2325, CAERØ* ELEMENT NØ. ******** REFERENCED ØN A SET2 CARD DØES NØT EXIST.

A SET2 card points to a CAERØi which was not included.

2326 *** USER FATAL MESSAGE 2326, CAERØ* ELEMENT NØ. ******** REFERENCES AEFACT CARD NØ. ******** WHICH DØES NØT EXIST.

The listed CAERØi card requires one AEFACT card for LSPAN.

2327 *** USER FATAL MESSAGE 2327, CAERØ* ELEMENT NØ. ******** REFERENCES AEFACT CARD NØ. ******** WHICH DØES NØT EXIST.

The listed CAERØi card requires one AEFACT card for LCHØRD.

2328 *** USER FATAL MESSAGE 2328, SET* AND SPLINE* CARDS REQUIRED.

At least one SET1 or SET2 card and at least one SPLINE1, SPLINE2 or SPLINE3 card required.

2329 *** USER FATAL MESSAGE 2329, DUPLICATE EXTERNAL ID NØ. ******** GENERATED.

The external IDs assigned to each generated box must be unique.

2330 *** USER FATAL MESSAGE 2330, SET1 ØR SPLINE3 CARD NØ. ******** REFERENCES EXTERNAL ID NØ. ******** WHICH DØES NØT EXIST.

External grid point IDs referenced on a SET1 or SPLINE3 card do not exist as structural grid points.

2331 *** USER FATAL MESSAGE 2331, BØX PICKED ØN SPLINE CARD NØ. ******** NØT GENERATED BY CAERØ CARD NØ. ********.

SPLINE card ******** points to a box which was not generated by the CAERØi card.

2332 *** USER WARNING MESSAGE 2332, INVALID INPUT DATA DETECTED IN DATA BLØCK, ****, PRØCESSING STØPPED FØR THIS DATA BLØCK.

2333 *** SYSTEM INFØRMATIØN MESSAGE 2333, MØDULE DDRMM TERMINATED WITH VARIABLE IERRØR = **********.

2334 *** SYSTEM WARNING MESSAGE 2334, ILLEGAL MAJØR ØR MINØR ØFP-ID IDENTIFICATIØNS = ********* ********** DETECTED IN DATA BLØCK, ****, PRØCESSING ØF SAID DATA BLØCK DISCØNTINUED.

2335 *** SYSTEM WARNING MESSAGE 2335, THE AMØUNT ØF DATA IS NØT CØNSISTENT FØR EACH EIGENVALUE IN

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DATA BLØCK **** PRØCESSING ØF THIS DATA BLØCK TERMINATED.

2336 *** SYSTEM WARNING MESSAGE 2336, A CHANGE IN WØRD 2 ØF THE ØFP-ID RECØRDS ØF DATA BLØCK **** HAS BEEN DETECTED. PRØCESSING ØF THIS DATA BLØCK HAS BEEN TERMINATED.

2337 *** USER WARNING MESSAGE 2337, DATA BLØCK **** CAN NØT BE PRØCESSED DUE TØ A CØRE INSUFFICIENCY ØF APPRØXIMATELY ********** DECIMAL WØRDS.

2338 *** USER WARNING MESSAGE 2338, DATA BLØCK **** MAY NØT BE FULLY CØMPLETED DUE TØ A CØRE INSUFFICIENCY ØF APPRØXIMATELY ********** DECIMAL WØRDS.

2339 *** SYSTEM WARNING MESSAGE 2339, A CHANGE IN WØRD 2 ØF THE ØFP-ID RECØRDS ØF DATA BLØCK **** HAS BEEN DETECTED. PRØCESSING ØF THIS DATA BLØCK HAS BEEN TERMINATED.

2340 *** USER WARNING MESSAGE 2340, MØDULE **** ****, HAS BEEN REQUESTED TØ DØ UNSYMMETRIC DECØMPØSITIØN ØF A SYMMETRIC MATRIX.

2341 *** USER WARNING MESSAGE 2341, MØDULE **** **** HAS BEEN FURNISHED A SQUARE MATRIX MARKED UNSYMMETRIC FØR SYMMETRIC DECØMPØSITIØN.

2342 *** USER WARNING MESSAGE 2342, UNRECØGNIZED APPRØACH PARAMETER ******** IN GPFDR INSTRUCTIØN.

The solution approach parameter can only be STATICS, REIGEN, DS0, DS1, FREQ, TRAN, BLK0, BLK1, CEIGEN or PLA corresponding to the Rigid Format used.

2343 *** SYSTEM WARNING MESSAGE 2343, DATA BLØCK, *****, IS EITHER NØT -EQEXIN- ØR PØSSIBLY INCØRRECT.

2344 *** SYSTEM WARNING MESSAGE 2344, GPFDR FINDS ELEMENT = **** ****, HAS AN ECT ENTRY LENGTH TØØ LØNG FØR A PRØGRAM LØCAL ARRAY.

2345 *** SYSTEM WARNING MESSAGE 2345, GPFDR FINDS AND IS IGNØRING UNDEFINED ECT DATA WITH LØCATE NUMBERS = ******** ******** ********.

2346 *** SYSTEM WARNING MESSAGE 2346, GPFDR FINDS DATA FØR EL-TYPE = **********, IN DATA BLØCK, ********** NØT TØ BE IN AGREEMENT WITH THAT WHICH IS EXPECTED.

2347 *** USER WARNING MESSAGE 2347, GPFDR FINDS TØØ MANY ACTIVE CØNNECTING GRID PØINTS FØR ELEMENT ID = **********.

2348 *** SYSTEM WARNING MESSAGE 2348, GPFDR DØES NØT UNDERSTAND THE MATRIX-DICTIØNARY ENTRY FØR ELEMENT ID = **********.

2349 *** SYSTEM WARNING MESSAGE 2349, GPFDR FINDS AN ELEMENT ENTRY CØNNECTING PIVØT SIL = **********, ØN DATA BLØCK ***** TØØ LARGE FØR A LØCAL ARRAY. ENTRY IS BEING IGNØRED.

2350 *** SYSTEM WARNING MESSAGE 2350, GPFDR CANNØT FIND PIVØT SIL = **********, AMØNG THE SILS ØF ELEMENT ID = **********, AS READ FRØM DATA BLØCK, *****, ENTRY THUS IGNØRED.

2351 *** USER INFØRMATIØN MESSAGE 2351, A FØRCE CØNTRIBUTIØN DUE TØ ELEMENT TYPE = **** ****, ØN PØINT ID = **********, WILL NØT APPEAR IN THE GRID-PØINT-FØRCE-BALANCE SUMMARY.

2352 *** SYSTEM WARNING MESSAGE 2352, GPFDR IS NØT ABLE TØ FIND PIVØT SIL = ********** AS READ FRØM DATA BLØCK ***** IN TABLE ØF SILS.

2353 *** USER WARNING MESSAGE 2353, INSUFFICIENT CØRE TØ HØLD ALL NØN-ZERØ APP-LØAD AND F-ØF-SPC ØUTPUT LINE ENTRIES ØF GRID-PØINT-FØRCE-BALANCE REQUESTS. SØME PØINTS REQUESTED FØR ØUTPUT WILL BE MISSING THEIR APP-LØAD ØR F-ØF-SPC CØNTRIBUTIØN IN THE PRINTED BALANCE.

2354 *** SYSTEM WARNING MESSAGE 2354, GPFDR MØDULE IS UNABLE TØ CØNTINUE AND HAS BEEN TERMINATED DUE TØ ERRØR MESSAGE PRINTED ABØVE ØR BELØW THIS MESSAGE. THIS ERRØR ØCCURRED IN GPFDR CØDE WHERE THE VARIABLE -NERRØR- WAS SET = *****.

2355 *** USER FATAL MESSAGE 2355, GRID PØINT CØØRDINATES ØF ELEMENT ******** ARE IN ERRØR. ØNE ØR MØRE ØF THE R-CØØRDINATES ARE ZERØ ØR NEGATIVE.

2357 *** USER WARNING MESSAGE 2357, ØNE VECTØR (DEFAULT) WILL BE CØMPUTED IN THE CØMPLEX REGIØN.

If more than one vector is desired from the Hessenburg method, make a specific request on the EIGC card.

2358 *** USER WARNING MESSAGE 2358, SYMMETRIC SCRIPT-AF MATRIX (HREE) ASSUMED IN RADMTX.

2359 *** USER WARNING MESSAGE 2359, CØL *****, RØW ***** ØF RADMTX IS NEGATIVE.

2360 *** USER FATAL MESSAGE 2360, TØTAL VIEW FACTØR (FA/A), FØR ELEMENT ******** IS ************** (ELEMENT AREA IS **************).

Provides view factors and areas for all elements with a view factor greater than 1.01. This message is also a WARNING for all elements with a view factor between .99 and 1.01 provided the NASTRAN card SYSTEM(58)=1, is included in the deck.

2361 *** USER INFØRMATIØN MESSAGE 2361, **** ELEMENTS HAVE A TØTAL VIEW FACTØR (FA/A) LESS THAN 0.99, ENERGY MAY BE LØST TØ SPACE.

Provides the total number of elements with a view factor less than .99.

2362 *** USER FATAL MESSAGE 2362, CHBDY CARDS WITH DUPLICATE IDS FØUND IN EST, CHBDY ID NUMBER = **********.

2363 *** SYSTEM WARNING MESSAGE 2363, SSG2B FØRCED MPYAD CØMPATIBILITY ØF MATRIX ØN ***** FRØM (*****, *****) TØ (*****, *****).

This message identifies a matrix and its initial size (row, column) and its changed size (row, column) so that it is compatible with MPYAD operations.

2364 *** USER FATAL MESSAGE 2364, GRID PØINT CØØRDINATES ØF ELEMENT ******** ARE IN ERRØR. ØNE ØR MØRE ØF THE THETA-CØØRDINATES ARE NØNZERØ.

2365 *** USER WARNING MESSAGE 2365, INSUFFICIENT CØRE FØR HESSENBURG METHØD. SWITCHING TØ INVERSE PØWER.

2366 *** USER FATAL MESSAGE 2366, REGIØN IMPRØPERLY DEFINED ØN EIGC CARD.

If insufficient core has caused an automatic switch from Hessenburg method to Inverse Power method, the EIGC card must have the region(s) defined (they are ignored for the Hessenburg method). Either increase core to use the Hessenburg method or define the region(s) for Inverse Power.

2367 *** USER WARNING MESSAGE 2367, FREQUENCY F1 (FIELD 4) ØN THE EIGR BULK DATA CARD IS NEGATIVE. IT IS ASSUMED TØ BE ZERØ FØR CALCULATIØN PURPØSES.

2369 *** USER WARNING MESSAGE 2369, WHEEL MUST HAVE FEWER THAN 256 SPØKES. INPUT MØDULE RESETTING TØ 255.

See Section 2.6 for a discussion of INPUT module sample 8.

2370 *** USER WARNING MESSAGE 2370, MULTIPØINT CØNSTRAINT FØRCES NØT CALCULATED IN ****** DUE TØ MISSING INPUT FILE.

2371 *** USER WARNING MESSAGE 2371, EQUILIBRIUM FØRCES NØT CALCULATED IN ****** DUE TØ MISSING INPUT FILE.

2372 *** USER WARNING MESSAGE 2372, ****** IS UNABLE TØ CALCULATE RIGID BØDY TRANSFØRMATIØN FØR SCALAR MØDEL.

2373 *** USER WARNING MESSAGE 2373, ØNLY SØRT1-REAL SUPPØRTED IN ********.

2374 *** USER WARNING MESSAGE 2374, INSUFFICIENT CØRE TØ PRØCESS MØRE THAN **** VECTØRS IN ****.

Output module EQMCK needs 6 words for loads, MPCs and SPCs for each subcase or eigenvalue plus 2 (statics) or 3 (eigenvalue) buffers.

2375 *** SYSTEM WARNING MESSAGE 2375, MØDULE ******** HAS BEEN REQUESTED TØ DECØMPØSE A RECTANGULAR MATRIX.

Symmetric decomposition will not accept rectangular matrix input.

2376 *** USER WARNING MESSAGE 2376, INSUFFICIENT CØRE IN ****. HAS ****, NEEDS ****.

2377 (A) *** USER WARNING MESSAGE 2377A, MATRIX CØNDITIØNING ERRØRS GIVEN WITH EXTERNAL ID.

2377 (B) *** USER WARNING MESSAGE 2377B, MATRIX CØNDITIØNING ERRØRS GIVEN WITH INTERNAL ID.

Symmetric decomposition diagnostics follow. Both the input and decomposed diagonal are printed. Only available when module SDCMPS is used.

2378 *** USER INFØRMAIØN MESSAGE 2378, **** ESTIMATE ØF CPU TIME FØR MT=****, PASSIVE CØL.=****, ACTIVE CØL.=****, SPILL=****.

Seconds of CPU time for each of the above operations is given when module SDCMPS is used.

2379 *** SYSTEM FATAL MESSAGE 2379, LØGIC ****** ERRØR IN SDCMPS.

2380 *** USER WARNING MESSAGE 2380, MULTIPØINT CØNSTRAINT FØRCES NØT ØUTPUT IN ******, SEE QUEUED MESSAGES.

Other message(s) follow(s) indicating the reason(s) why a request for MPCFØRCE in the Case Control Deck is being ignored.

2381 *** SYSTEM FATAL MESSAGE 2381, LØGIC ERRØR ****** IN SDCMPS.
CØNTENTS ØF /SDCØMX/ FØLLØW --

2382 *** USER WARNING MESSAGE 2382, ELEMENT MATRICES FØR ELEMENTS CØNGRUENT TØ ELEMENT ID = ***** ***** WILL BE RE-CØMPUTED AS THERE IS INSUFFICIENT CØRE AT THIS TIME TØ HØLD CØNGRUENCY MAPPING DATA.
ADDITIØNAL CØRE NEEDED = **** WØRDS.

2383 *** SYSTEM WARNING MESSAGE 2383, UNABLE TØ LØCATE CØNGRUENCY MAPPING DATA FØR ELEMENT ID = **********. ELEMENT MATRICES FØR THIS ELEMENT WILL, THEREFØRE, BE RE-CØMPUTED.

2384 *** USER WARNING MESSAGE 2384, CØNGRUENCY ØF ELEMENT ID = ********** WILL BE IGNØRED AND ITS ELEMENT MATRICES WILL BE RE-CØMPUTED AS THERE IS INSUFFICIENT CØRE AT THIS TIME TØ PERFØRM CØNGRUENCY MAPPING CØMPUTATIØNS.
ADDITIØNAL CØRE NEEDED = **** WØRDS.

2385 *** USER WARNING MESSAGE 2385, DESIRED NUMBER ØR EIGENVALUES EXCEED THE EXISTING NUMBER, ALL EIGENSØLUTIØNS WILL BE SØUGHT.

The desired number of eigenvalues specified on the EIGB card (NEP) or the EIGR card (ND) exceeds the rank of the $[K^d_{aa}]$ or $[M_{aa}]$ matrix.

2386 *** USER FATAL MESSAGE 2386, STIFFNESS MATRIX SINGULARITY CANNØT BE REMØVED BY SHIFTING.

Check the specification of masses on CØNM1, CØNM2, CMASSi, material definition and element property cards to ensure that the degrees-of-freedom in the analysis set are not all massless.

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2387 *** USER WARNING MESSAGE 2387, PRØBLEM SIZE REDUCED TØ **** DUE TØ ØRTHØGANILITY DRIFT ØR NULL TRIAL VECTØR.
ALL EXISTING MØDES MAY HAVE BEEN ØBTAINED. USE DIAG 16 TØ DETERMINE ERRØR BØUNDS.

The Tridiagonal Reduction method cannot generate a reduced problem size of the order prescribed in Section 10.6.2.3 of the Theoretical Manual. However, the desired number of accurate eigenvalues specified on the EIGB card (NEP) or the EIGR card (ND) may have been obtained. A detailed list of the computed error bounds could have been obtained by requesting DIAG 16 in the Executive Control Deck.

2388 *** USER WARNING MESSAGE 2388, USER SPECIFIED RANGE NØT USED FØR FEER BUCKLING, THE RØØTS ØF LØWEST MAGNITUDE ARE ØBTAINED.

The value of L1 specified on the EIGB card is ignored for buckling analysis by the Tridiagonal Reduction (FEER) method.

2389 *** USER WARNING MESSAGE 2389, PRØBLEM SIZE REDUCED. NØ MØRE TRIAL VECTØRS CAN BE ØBTAINED.

The desired number of eigenvalues specified on the EIGB card (NEP) or the EIGR card (ND) exceeds the number that can be calculated by the Tridiagonal Reduction (FEER) method.

Check whether the requested number of eigenvalues exceeds the rank of the $[K^d_{aa}]$ or $[M_{aa}]$ matrix, which equals the number of existing eigenvalues.

2390 *** USER WARNING MESSAGE 2390, **** FEWER ACCURATE EIGENSØLUTIØNS THAN THE **** REQUESTED HAVE BEEN FØUND. USE DIAG 16 TØ DETERMINE ERRØR BØUNDS.

The number of eigenvalues passing the eigenvalue relative-error test is less than the number requested on the EIGB or EIGR card. The maximum allowable error is specified in field 5 on the above cards. A detailed list of the computed error bounds could have been obtained by requesting DIAG 16 in the Executive Control Deck. A checkpoint and restart should be employed to obtain additional accurate eigensolutions.

2391 *** SYSTEM FATAL MESSAGE 2391, PRØGRAM LØGIC ERRØR IN FEER.

An unexpected EØF or word count has been encountered. This is caused by a conflict between subroutine FCNTL and GINØ.

2392 *** USER INFØRMATIØN MESSAGE 2392, **** MØRE ACCURATE EIGENSØLUTIØNS THAN THE **** REQUESTED HAVE BEEN FØUND. USE DIAG 16 TØ DETERMINE ERRØR BØUNDS.

The number of eigenvalues passing the eigenvalue relative-error test is greater than the number requested on the EIGB or EIGR card. The maximum allowable error is specified in field 5 on the above cards. A detailed list of the computed error bounds could have been obtained by requesting DIAG 16 in the Executive Control Deck.

2393 *** USER WARNING MESSAGE 2393, THE REDUCED-SYSTEM EIGENVECTØR CØRRESPØNDING TØ EIGENVALUE **** DØES NØT MEET CØNVERGENCE CRITERIØN. ABSØLUTE RELATIVE ERRØR BETWEEN SUCCESSIVE ITERATES IS ****.

The accuracy of the corresponding physical eigenvector is in doubt. Refer to the Eigenvalue Summary Table for the largest error in the generalized mass matrix.

2396 *** USER WARNING MESSAGE 2396, SDCØMP CØMPUTED A ZERØ ØN THE DIAGØNAL. A VALUE ØF 1.0E-10 WILL BE USED. THE ACCURACY ØF THE DECØMPØSITIØN MAY BE IN DØUBT.

The matrix being decomposed is singular or a diagonal element is less than zero in the case of Cholesky decomposition.

2397 *** USER FATAL MESSAGE 2397, INVALID TØ HAVE AN Ø-SET WITH A NULL A-SET.

There must be at least one degree of freedom in the A-SET even though EPØINTS may be present.

2398 *** USER FATAL MESSAGE 2398, MPYAD REQUIRES SIGN ØF A*B TØ BE -1, 0 ØR +1.

2399 *** USER WARNING MESSAGE 2399, ØNLY THE FIRST ***** EIGENSØLUTIØNS CLØSEST TØ THE SHIFT PØINT (F1 ØR ZERØ) PASS THE FEER ACCURACY TEST FØR EIGENVECTØRS.

2401 *** USER WARNING MESSAGE 2401, ******** MATRIX IS NULL. AN ARBITRARY VALUE ØF 1.0 IS THEREFØRE ASSIGNED TØ THE RIGID BØDY ERRØR RATIØ (EPSILØN SUB E).

2402 *** USER FATAL MESSAGE 2402, NULL DIFFERENTIAL STIFFNESS MATRIX GENERATED IN SUBRØUTINE DS1A.

2404 *** USER FATAL MESSAGE 2404, GRID PØINTS 1 AND 3 ØF TRIM6 WITH ELEMENT ID = ******** HAVE SAME CØØRDINATES.

2405 *** USER FATAL MESSAGE 2405, GRID PØINTS 1, 3, AND 5 APPEAR TØ BE ØN A STRAIGHT LINE. ELEMENT TRIM6 WITH ID = ********.

2406 *** USER FATAL MESSAGE 2406, GRID PØINTS 1 AND 5 HAVE SAME CØØRDINATES. ELEMENT TRIM6 WITH ID = ********.

2407 *** USER FATAL MESSAGE 2407, MATRIX RELATING GENERALIZED PARAMETERS AND GRID PØINT DISPLACEMENTS IS SINGULAR. CHECK CØØRDINATES ØF ELEMENT TRIM6 WITH ID = ********.

2408 *** USER FATAL MESSAGE 2408, GRID PØINTS 1 AND 3 ØF TRPLT1 WITH ELEMENT ID = ******** HAVE SAME CØØRDINATES.

2409 *** USER FATAL MESSAGE 2409, GRID PØINTS 1, 3, AND 5 APPEAR TØ BE ØN A STRAIGHT LINE. ELEMENT TRPLT1 WITH ID = ********.

2410 *** USER FATAL MESSAGE 2410, GRID PØINTS 1 AND 5 HAVE SAME CØØRDINATES. ELEMENT TRPLT1 WITH ID = ********.

2411 *** USER FATAL MESSAGE 2411, MATRIX RELATING GENERALIZED PARAMETERS AND GRID PØINT DISPLACEMENTS IS SINGULAR. CHECK CØØRDINATES ØF ELEMENT TRPLT1 WITH ID = ********.

2412 *** USER FATAL MESSAGE 2412, A SINGULAR MATERIAL MATRIX FØR ELEMENT ID = ******** HAS BEEN DETECTED BY SUBRØUTINE TLØDT1 WHILE TRYING TØ CØMPUTE THERMAL LØADS WITH TEMPP2 CARD DATA.

The thermal load vector generated by TEMPP2 data is not correctly applied to a TRPLT1 element.

2413 *** USER FATAL MESSAGE 2413, GRID PØINTS 1 AND 3 ØF TRSHL WITH ELEMENT ID = ******** HAVE SAME CØØRDINATES.

2414 *** USER FATAL MESSAGE 2414, GRID PØINTS 1, 3, AND 5 APPEAR TØ BE ØN A STRAIGHT LINE. ELEMENT TRSHL WITH ID = ********.

2415 *** USER FATAL MESSAGE 2415, GRID PØINTS 1 AND 5 HAVE SAME CØØRDINATES. ELEMENT TRSHL WITH ID = ********.

2416 *** USER FATAL MESSAGE 2416, MATRIX RELATING GENERALIZED PARAMETERS AND GRID PØINT DISPLACEMENTS IS SINGULAR. CHECK CØØRDINATES ØF ELEMENT TRSHL WITH ID = ********.

2417 *** USER FATAL MESSAGE 2417, A SINGULAR MATERIAL MATRIX FØR ELEMENT ID = ******** HAS BEEN DETECTED BY SUBRØUTINE TLØDSL WHILE TRYING TØ CØMPUTE THERMAL LØADS WITH TEMPP2 CARD DATA.

The thermal load vector generated by TEMPP2 data is not correctly applied to TRSHL element.

2418 *** USER FATAL MESSAGE 2418, MATERIAL ID FØR MEMBRANE EFFECTS IS LESS THAN ØR EQUAL TØ ZERØ FØR TRSHL ELEMENT WITH ID = ********.

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2419 *** SYSTEM FATAL MESSAGE 2419, PIVØT PØINT IS NØT EQUAL TØ TRSHL ELEMENT GRID PØINTS FØR ELEMENT ID = ********.

An error in the coordinate system transformation has occurred. Temporary avoidance: remove coordinate system ID from field 7 of the GRID (or GRDSET) card.

2422 *** USER WARNING MESSAGE 2422, VISC DATA NØT PRØCESSED BY EMGPRØ.

CVISC data cards are used only in the direct method of dynamic problem formulations (Rigid Formats 7, 8 and 9). A warning is issued when these cards are encountered in the modal method of dynamic problem formulations (Rigid Formats 10, 11 and 12).

2423 *** USER FATAL MESSAGE 2423, DEPENDENT CØMPØNENT SPECIFIED MØRE THAN ØNCE ØN MPC CARDS AND/ØR IN RIGID ELEMENTS.
SIL VALUE = ********.

The use of DIAG 21 in the Executive Control Deck will show the SIL (internal DØF) corresponding to the duplicated component.

2424 *** USER FATAL MESSAGE 2424, MACH BØX CØNTRØL PØINTS IMPRØPER. SINGULAR MATRIX RESULTED.

2425 *** USER FATAL MESSAGE 2425, MACH BØX GENERATIØN ØF BØXES FAILED.

2426 *** USER FATAL MESSAGE 2426, MACH NUMBER ********** WAS NØT FØUND ØN AEFACT CARD ********.

2427 *** USER FATAL MESSAGE 2427, SINGULAR MATRIX FØR INTERPØLATIØN IN ********.

2428 *** USER FATAL MESSAGE 2428, MACH NUMBER ********** WAS NØT FØUND IN PISTØN THEØRY ALPHA ARRAY.

2429 *** USER FATAL MESSAGE 2429, WRØNG NUMBER ØF WØRDS ØR CARD NØT FØUND FØR CARD ID ******** ASSØCIATED WITH CAERØ* ID ********.

2430 *** SYSTEM WARNING MESSAGE 2430, REQUESTED ******** PRECISIØN ******** BY ********. ******** IS LØGICAL CHØICE.

This message is issued when single or double precision is prescribed for a matrix utility module but could be better prescribed based on the data.

2431 *** SYSTEM WARNING MESSAGE 2431, REQUESTED TYPE ******** BY ********. TYPE ******** IS LØGICAL CHØICE.

This message is issued when real or complex output is prescribed for a matrix utility module but should be prescribed as indicated.

2432 *** USER INFØRMATIØN MESSAGE 2432, DIAG 19 MPYAD SUMMARY.

Information on next two lines is MPYAD matrix data summary listed on system output file on CDC and UNIVAC or on log file (Unit 4) on IBM and VAX.

2433 *** USER INFØRMATIØN MESSAGE 2433, MPYAD METHØD ****, NBR PASSES = ****, EST TIME = ****.

DIAG 19 MPYAD Method Summary listed on system output file on CDC and UNIVAC or on log file (Unit 4) on IBM and VAX.

2434 *** USER INFØRMATIØN MESSAGE 2434, MPYAD -- NULL MATRIX PRØDUCT.

DIAG 19 MPYAD message.

6.5 FUNCTIONAL MODULE MESSAGES (3001 THRU 4000)

3001 *** SYSTEM FATAL MESSAGE 3001, ATTEMPT TØ ØPEN DATA SET *** IN SUBRØUTINE ****** WHICH WAS NØT DEFINED IN FIST.

Subroutine did not expect data block to be purged. Check data block requirements for module. This message is also a WARNING when STRESS output is requested in a heat transfer problem.

3002 *** SYSTEM FATAL MESSAGE 3002, EØF ENCØUNTERED WHILE READING DATA SET ********(FILE ***) IN SUBRØUTINE ******.

This message is issued when an end-of-file occurs while trying to skip the header record. The data block is not in the proper format.

3003 *** SYSTEM FATAL MESSAGE 3003, ATTEMPT TØ READ PAST THE END ØF A LØGICAL RECØRD IN DATA SET ********(FILE ***) IN SUBRØUTINE ********.

This message is issued when the file is positioned at the beginning of a logical record and the record does not contain at least three words. Data block is not in proper format.

3004 *** SYSTEM FATAL MESSAGE 3004, INCØNSISTENT TYPE FLAGS ENCØUNTERED WHILE PACKING DATA SET ****.

3005 *** USER FATAL MESSAGE 3005, ATTEMPT TØ ØPERATE ØN SINGULAR MATRIX **** IN SUBRØUTINE ****.

A disgonal term does not exist for a column of (U). This is normally detected in DECØMP implying care was not taken in processing singular matrices in the calling routine.

3006 *** SYSTEM FATAL MESSAGE 3006, BUFFER ASSIGNED WHEN ØPENING DATA BLØCK **** FILE (****) CØNFLICTS WITH BUFFERS CURRENTLY ØPEN.

Computation of buffer pointers or allocation of open core is in error.

3007 *** SYSTEM FATAL MESSAGE 3007, ILLEGAL INPUT TØ SUBRØUTINE ****.

Subroutine **** has encountered data which it cannot process. This error should not be caused by user input data. A system or programming error is indicated. Go directly to the subroutine listing or description to determine the exact cause of the problem.

3008 *** SYSTEM FATAL MESSAGE 3008, INSUFFICIENT CØRE AVAILABLE FØR SUBRØUTINE ********. ADDITIØNAL CØRE REQUIRED = **** WØRDS.

Insufficient open core was available to meet the needs of the subroutine indicated. Increase Region Size, Field Length, HICØRE allocation or the length of the open core CØMMØN block, depending on the machine being used.

3009 *** SYSTEM FATAL MESSAGE 3009, DATA TRANSMISSIØN ERRØR ØN DATA SET *******(FILE ***).

A conflict exists between the SGINØ subroutine for the UNIVAC 1108 and the resident NTRAN$. Either record SGINØ or remove the PLØT request from the NASTRAN job.

3010 *** SYSTEM FATAL MESSAGE 3010, ATTEMPT TØ MANIPULATE DATA SET ********(FILE ***) BEFØRE ØPENING FILE.

An operation other than ØPEN or CLØSE is requested on a file which is not defined in the FIST.

3011 *** SYSTEM FATAL MESSAGE 3011, ATTEMPT TØ WRITE A TRAILER ØN FILE *** WHEN IT HAS BEEN PURGED.

The file did not exist in the FIST when WRTTRL was called.

3012 *** SYSTEM FATAL MESSAGE 3012, ATTEMPT TØ ØPEN DATA SET ********(FILE ***) WHICH HAS ALREADY BEEN ØPENED.

GINØ ØPEN was called while the file was already open.

3013 *** SYSTEM FATAL MESSAGE 3013, ATTEMPT TØ READ DATA SET ********(FILE ***) WHEN IT WAS ØPENED FØR ØUTPUT.

GINØ was called to READ a data block opened for output.

3014 *** SYSTEM FATAL MESSAGE 3014, ATTEMPT TØ WRITE DATA SET ********(FILE ***) WHEN IT WAS ØPENED FØR INPUT.

GINØ was called to WRITE a data block opened for input.

3015 *** SYSTEM FATAL MESSAGE 3015, ATTEMPT TØ FWDREC ØN DATA SET ********(FILE ***) WHEN IT WAS ØPENED FØR ØUTPUT.

GINØ was called to FWDREC a file opened for output.

3016 *** SYSTEM FATAL MESSAGE 3016, **** MATRIX IS NØT IN PRØPER FØRM IN SUBRØUTINE ****.

This implies that the input matrix is not in the proper form or type acceptable to the subroutine. Check the trailer information on the matrix and the subroutine description for the discrepancy.

3017 *** USER WARNING MESSAGE 3017, ØNE ØR MØRE GRID PØINT SINGULARITIES HAVE NØT BEEN REMØVED BY SINGLE ØR MULTI-PØINT CØNSTRAINTS.

Singularities or near singularities may exist at the grid point level. The listed singularities should be examined for data errors. The check performed here is neither necessary nor sufficient for a singular matrix.

3018 *** SYSTEM FATAL MESSAGE 3018, MØDULE ********, SEQUENCE NØ. ***, REQUIREMENTS EXCEED AVAILABLE FILES.

Segment File Allocator (SFA) did not have sufficient logical files available to fulfill the request of the module. Cut module requirements or increase the logical files within the computer system. See Section 5 of the Programmer's Manual.

3019 *** USER FATAL MESSAGE 3019, MAXIMUM LINE CØUNT EXCEEDED IN SUBRØUTINE **** LINE CØUNT EQUALS ****.

The total number of lines written on the system output file has exceeded the set limit (default value is 20,000). If you wish to increase this value, include a card of the form "MAXLINES=n" in your Case Control Deck.

3020 *** SYSTEM FATAL MESSAGE 3020, GNFIST ØVERFLØWED FIST TABLE AT SEQUENCE NØ. *** DATA SET ********.

Generate FIST (GNFIST) routine overflowed FIST /XFIST/. Increase compiled size. See Section 2 of the Programmer's Manual.

3021 *** SYSTEM FATAL MESSAGE 3021, FILE *** NØT DEFINED IN FIST.

An operation other than ØPEN or CLØSE is requested on a file which is not defined in the FIST.

3022 *** SYSTEM WARNING MESSAGE 3022, DATA SET ******** IS REQUIRED AS INPUT AND IS NØT ØUTPUT BY A PREVIØUS MØDULE IN THE CURRENT DMAP RØUTE.

Segment File Allocator (SFA) detected that an input data block to a future module has not been generated. If the future module requires that this data block exist, the module may terminate with a fatal error.

This message may occur (and most often does) when the Segment File Allocator has removed from its tables (due to a need for more room) previously purged data blocks. In this case no error or even a warning is implied.

3023 *** USER INFØRMATIØN MESSAGE 3023--PARAMETERS FØR SYMMETRIC DECØMPØSITIØN ØF DATA BLØCK ******** (N = *****) TIME ESTIMATE = ********.

C AVG = ******	S AVG = ******	PC MAX = ******
PC AVG = ******	ADDITIØNAL CØRE = *******	PC GRØUPS = ******
SPILL GRØUPS = ******	C MAX ******	PREFACE LØØPS = ******

N is the number of rows in the data block; TIME is the estimate (in seconds) to perform the decomposition; C AVG is the average number of active columns per pivot row; PC AVG is the average number of passive columns at each active termination point; SPILL GRØUPS is the number of spill groups; S AVG is the average number of rows in each spill group; ADDITIØNAL CØRE (positive) is the amount of core required to avoid spill, (negative) is the amount of unused core; C MAX is the maximum number of active columns in any one pivot row; PC MAX is the maximum number of passive columns at any one active column termination point; PC GRØUPS is the number of active column termination points; PREFACE LØØPS is the number of times the preface of the decomposition subroutine is executed.

3024 *** USER INFØRMATIØN MESSAGE 3024, THE BANDWIDTH ØF MATRIX **** EXCEEDS THE MAXIMUM BANDWIDTH. A MAXIMUM BANDWIDTH ØF **** WILL BE USED.

This message indicates that a matrix has scattered terms way off the diagonal (i.e., a large bandwidth). Instead of searching all combinations of B and C, the search is started at the maximum bandwidth.

3025 *** SYSTEM FATAL MESSAGE 3025, ILLEGAL INDEX IN ACTIVE RØW ØR CØLUMN CALCULATIØN IN ****.

Possible machine error. Rerun problem. If error persists, a code error exists in the decomposition routine.

3026 *** SYSTEM FATAL MESSAGE 3026, MATRIX **** EXCEEDS MAXIMUM ALLØWABLE SIZE FØR BANDWIDTH PLUS ACTIVE CØLUMNS. BMAX = ****, CMAX = ****.

Sufficient space was not reserved for the generation of the B vs. C vector. SDCØMP should be recompiled to increase BMAX and CMAX.

3027 *** USER INFØRMATIØN MESSAGE 3027, **** DECØMPØSITIØN ØF DATA BLØCK **** (N = ****) TIME ESTIMATE IS ******** SECØNDS.

Gives the estimated time required for a decomposition in seconds and the type of matrix, i.e., complex, real (double or single precision), symmetric or unsymmetric.

3028 *** USER INFØRMATIØN MESSAGE 3028, B = ****, BBAR = ****, C = ****, CBAR = ***, R = ****.

Gives the upper bandwidth (B), lower bandwidth (BBAR), number of active columns (C), and active rows (CBAR) used in the unsymmetric decomposition.

3029 *** SYSTEM FATAL MESSAGE 3029, PHYSICAL END-ØF-FILE ENCØUNTERED ØN DATA SET **** (FILE ****).

Since logical end-of-files are used by GINØ, a physical end-of-file indicates an attempt to read beyond valid data.

3030 *** USER WARNING MESSAGE 3030, ØFP UNABLE TØ PRØCESS DATA BLØCK. A TABLE ØF THE DATA BLØCK FØLLØWS.

3031 *** Same as message 3032.

3032 *** USER FATAL MESSAGE 3032, UNABLE TØ FIND SELECTED SET (****) IN TABLE (****) IN SUBRØUTINE (****).

A particular set used in the problem was not included in the data. Good examples are loads, initial conditions, or frequency sets. Include the required data or change the Case Control Deck to select data already in problem. Set zero (0) has a special meaning. A set selection was required, but none was made. For example, no METHØD was selected for an eigenvalue extraction problem.

This message can also indicate that a LØAD card has referenced another LØAD card, which is not permitted.

3033 *** USER FATAL MESSAGE 3033, SUBCASE ID **** IS REFERENCED ØN ØNE ØR MØRE RANDPS CARDS BUT IS NØT A CURRENT SUBCASE ID.

The RANDPS set selected can only reference subcase identification numbers included in the current loop. All subcases in which the direct input matrices or transfer functions do not change are run together. Either add a subcase with referenced identification number, change your RANDPS cards or change the identification numbers on your current subcases.

3034 *** USER WARNING MESSAGE 3034, ØRTHØGØNALITY CHECK FAILED, LARGEST TERM = **** EPSI = ****.

The off-diagonal terms of the modal mass matrix are larger than the user input criteria on the EIGB or EIGR bulk data card. The eigenvectors are not orthogonal to this extent. This nonorthogonality is especially important if a modal formulation is contemplated.

3035 *** USER INFØRMATIØN MESSAGE 3035, FØR LØAD ** EPSILØN SUB E=*****.

This is an informative message reflecting the accumulated round-off error of the static solution.

3036 *** SYSTEM FATAL MESSAGE 3036, DATA SET ******** IS REQUIRED AS INPUT BUT HAS NØT BEEN GENERATED ØR PURGED.

The above mentioned data set is not accounted for on the ØPTP checkpoint dictionary. The message indicates a failure of the File Name Restart Table. As an interim measure, the user can use the ALTER feature to execute the proper module to create the needed data set.

3037 *** SYSTEM FATAL MESSAGE 3037, JØB TERMINATED IN SUBRØUTINE ****.

This message designates the subroutine in which the program terminated. It should be preceded by a user message which explains the cause of the termination. The module in which the program terminated can be found by examining the online time messages.

3038 *** SYSTEM FATAL MESSAGE 3038, DATA SET *** DØES NØT HAVE MULTIREEL CAPABILITY.

Computer hardware/software does not support multireel files.

3039 *** SYSTEM FATAL MESSAGE 3039, ENDSYS CANNØT FIND SAVE FILE.

File cannot be found to save and restore executive tables during link switching.

3040 *** SYSTEM FATAL MESSAGE 3040, ATTEMPT TØ WRITE DATA SET ********(FILE ***) WHEN IT IS AN INPUT FILE.

Input data blocks for a module (100 .LT. NAME .LT. 200) may be read only.

3041 *** USER WARNING MESSAGE 3041, EXTERNAL GRID PØINT *** DØES NØT EXIST ØR IS NØT A GEØMETRIC GRID PØINT. THE BASIC ØRIGIN WILL BE USED.

The reference grid point specified on the PARAM GRDPNT card for weight and balance calculations in GPWG cannot be used.

3042 *** USER WARNING MESSAGE 3042, INCØNSISTENT SCALAR MASSES HAVE BEEN USED. EPSILØN/DELTA = *****.

GPWG has detected inconsistent scalar masses. Direct masses have been used. Skew inertias will result. Examine your scalar masses and CØNM1 cards.

3043 *** USER FATAL MESSAGE 3043, UNCØNNECTED EXTRA PØINT (MØDAL CØØRDINATE=***) HAS BEEN DETECTED BY SUBRØUTINE ****.

Extra points must be connected via Direct Matrix Input (or Transfer Functions) in modal transient or frequency response.

3044 *** USER FATAL MESSAGE 3044, A PØINT ØN NØNLINEAR LØAD SET **** NØLIN **** IS NØT AN EXTRA PØINT. ØNLY EXTRA PØINTS MAY HAVE NØNLINEAR LØADS IN A MØDAL FØRMULATIØN.

Modal transient analysis (Rigid Format 12) will support nonlinear loads only on extra points. Pick another nonlinear load set.

3045 *** USER WARNING MESSAGE 3045, INSUFFICIENT TIME TØ CØMPLETE THE REMAINING ** SØLUTIØN(S) IN MØDULE ***.

The time specified on the NASTRAN TIME card has expired in the named module. The module will be terminated. NASTRAN will continue running until the time on the job card expires. Restart to obtain print-out, complete solutions or rerun problem.

3046 *** USER FATAL MESSAGE 3046, YØUR SELECTED LØADING CØNDITIØN, INITIAL CØNDITIØN, AND NØNLINEAR FØRCES ARE NULL. A ZERØ SØLUTIØN WILL RESULT..

Transient solution must have one of the above nonzero.

3047 *** USER FATAL MESSAGE 3047, NØ MØDES WITHIN RANGE AND LMØDES=0. A MØDAL FØRMULATIØN CANNØT BE MADE.

The modes used for a modal formulation must be selected by a PARAM card. Set LFREQ, HFREQ or LMØDES to request modes.

3048 *** SYSTEM FATAL MESSAGE 3048, BUFFER CØNTRØL WØRD INCØRRECT FØR GINØ **** ØPERATIØN ØN DATA BLØCK ****.

The buffer control word has been destroyed outside of GINØ or an attempt to READ a file opened to WRITE or similar error has occurred.

3049 *** SYSTEM FATAL MESSAGE 3049, GINØ UNABLE TØ PØSITIØN DATA BLØCK **** CØRRECTLY DURING **** ØPERATIØN.

A block number read does not match the expected block number. The file has been repositioned outside the GINØ environment or a machine or operating system error has occurred.

3050 *** USER FATAL MESSAGE 3050, INSUFFICIENT TIME REMAINING FØR DECØMPØSITIØN, ****. TIME ESTIMATE IS **** SECØNDS.

The time estimated for a decomposition exceeds the remaining time. Increase the time estimate for the run.

3051 *** USER FATAL MESSAGE 3051, INITIAL CØNDITIØN SET **** WAS SELECTED FØR A MØDAL TRANSIENT PRØBLEM. INITIAL CØNDITIØNS ARE NØT ALLØWED IN SUCH A PRØBLEM.

3052 *** USER WARNING MESSAGE 3052, A RANDØM REQUEST FØR CURVE TYPE - **** -, PØINT - **** CØMPØNENT - **** -, SPECIFIES TØØ LARGE A CØMPØNENT ID. THE LAST CØMPØNENT WILL BE USED.

3053 *** USER WARNING MESSAGE 3053, THE ACCURACY ØF EIGENVALUE **** IS IN DØUBT. GIVENS-QR FAILED TØ CØNVERGE IN **** ITERATIØNS.

Each eigenvalue is computed to the precision limits of each machine consistent with the maximum number of iterations allowed. A programming change would be required to increase the maximum iteration parameter.

3054 *** USER WARNING MESSAGE 3054, THE ACCURACY ØF EIGENVECTØR **** CØRRESPØNDING TØ THE EIGENVALUE **** IS IN DØUBT.

The eigenvector failed to converge in the allowable number of iterations. Particular attention should be given to the off-diagonal terms of the modal mass matrix (MI) to determine if this vector is orthogonal to the remaining vectors. These terms will be computed and checked if field 9 on the EIGR card contains a nonzero value. The message is expected in the case of close or multiple eigenvalues, even though the vectors are properly computed.

3055 *** USER FATAL MESSAGE 3055, AN ATTEMPT TØ MULTIPLY ØR MULTIPLY AND ADD NØN-CØNFØRMABLE MATRICES TØGETHER WAS MADE IN SUBRØUTINE ********.

The multiply/add subroutine requires conformable matrices. There are two possible cases:

1. $[X] = [A][B] + [C]$

The number of columns of [A] must be equal to the number of rows of [B] and the number of columns of [C] must be equal to the number of columns of [B] and the number of rows of [C] must be equal to the number of rows of [A].

2. $[X] = [A]^T[B] + [C]$

The number of rows of [A] must be equal to the number of rows of [B]; the number of columns of [C] must be equal to the number of columns of [B] and the number of rows of [C] must be equal to the number of columns of [A].

3056 *** USER FATAL MESSAGE 3056, NØ MASS MATRIX IS PRESENT BUT MASS DATA IS REQUIRED.

An operation with the mass matrix is required, such as a gravity loading condition, but none was created. A typical cause is the omission of RHØ on the MAT1 card.

3057 *** USER FATAL MESSAGE 3057, MATRIX **** IS NØT PØSITIVE DEFINITE.

A Cholesky decomposition was attempted on the above matrix, but a diagonal term was negative or equal to zero, such that the decomposition failed.

3058 *** USER WARNING MESSAGE 3058, EPSILØN IS LARGER THAN **** FØR SUBCASE ****.

The error residual (either ε_ℓ or ε_ϕ)

$$\varepsilon = \frac{\{u\}^T \{\delta P\}}{\{P\}^T \{u\}}$$ is larger than would be expected for

a well conditioned problem. Near singularities may exist.

3059 *** USER FATAL MESSAGE 3059, SET IDENTIFIER **** DØES NØT EXIST. ERRØR DETECTED IN SUBRØUTINE ****.

When describing displacement matrices, only those set identifiers (such as M or G) listed under DMAP module MATGPR (see Section 5.5) are legal set descriptors. Choose a set descriptor which is legal (and describes the matrices to be operated on).

3060 *** USER FATAL MESSAGE 3060, READ MØDULE FINDS THAT THE INPUT STIFFNESS AND/ØR MASS MATRIX IS NULL.

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3061 *** USER INFØRMATIØN MESSAGE 3061, THE MEASURE ØF NØN- PLANARITY IS **** FØR ELEMENT NUMBER ********.

The measure of non-planarity for isoparametric quadrilateral membrane elements is the distance from actual grid points to mean plane divided by the average length of the diagonals. This message is issued only when the absolute value of this measure is greater than .01.

3062 *** SYSTEM FATAL MESSAGE 3062, HMAT MATERIAL RØUTINE CALLED IN A NØN-HEAT-TRANSFER PRØBLEM.

3063 *** SYSTEM WARNING MESSAGE 3063, INPUT FØRCES DATSDRHA BLØCK DØES NØT HAVE CØRRECT DATA.

3064 *** SYSTEM WARNING MESSAGE 3064, INCØNSISTENT HBDY DATA RECØRDS. ********** **********.

3065 *** SYSTEM WARNING MESSAGE 3065, THERE IS NØ EST DATA FØR HBDY ELEMENT ID = **********.

3066 *** USER WARNING MESSAGE 3066, THERE IS NØ TLØAD1 ØR TLØAD2 DATA FØR LØAD-ID = **********.

3067 *** USER WARNING MESSAGE 3067, LØAD SET ID = ********** IS NØT PRESENT.

3068 *** SYSTEM WARNING MESSAGE 3068, UNRECØGNIZED CARD TYPE = ********** FØUND IN -SLT- DATA BLØCK.

3069 *** USER WARNING MESSAGE 3069, ØUTPUT DATA BLØCK FØR FØRCES IS PURGED.

3070 *** USER WARNING MESSAGE 3070, QGE IS REQUIRED BY THIS MØDULE AND IS PURGED. NØ ØUTPUT FILE HAS BEEN CREATED.

3071 *** SYSTEM WARNING MESSAGE 3071, EXTRA DATA IN RADLST RECØRD ØF MATPØØL DATA BLØCK IGNØRED.

3072 *** USER WARNING MESSAGE 3072, TØØ MANY MATRIX VALUES INPUT VIA RADMTX BULK DATA FØR CØLUMN ********. EXTRA VALUES IGNØRED AS MATRIX SIZE IS DETERMINED TØ BE ØF SIZE ******** FRØM RADLST CØUNT ØF ELEMENT ID-S.

3073 *** USER FATAL MESSAGE 3073, NØ -HBDY- ELEMENT SUMMARY DATA IS PRESENT FØR ELEMENT ID = ********, WHICH APPEARS ØN A -RADLST- BULK DATA CARD.

3074 *** USER FATAL MESSAGE 3074, CØLUMN ******** ØF THE Y MATRIX IS NULL.

3075 *** USER FATAL MESSAGE 3075, INTERMEDIATE MATRIX Y IS SINGULAR.

3076 *** SYSTEM FATAL MESSSAGE 3076, GPTT DATA IS NØT IN SØRT BY INTERNAL ID.

3077 *** USER FATAL MESSAGE 3077, THERE IS NØ GRID PØINT TEMPERATURE DATA ØR DEFAULT TEMPERATURE DATA FØR SIL PØINT ******** AND PØSSIBLY ØTHER PØINTS.

3078 *** USER FATAL MESSAGE 3078, NØ GPTT DATA IS PRESENT FØR TEMPERATURE SET ********.

3079 *** USER FATAL MESSAGE 3079, THERE ARE NØ -HBDY-ELEMENTS PRESENT.

3080 *** USER FATAL MESSAGE 3080, ERRØR IN QVECT DATA, INTEGER VALUES SPECIFIED FØR THERMAL FLUX VECTØR CØMPØNENTS IN A NØN-TRANSIENT ANALYSIS. ELEMENT ID = ****.

3081 *** SYSTEM FATAL MESSAGE 3081, INCØNSISTENT USET DATA DETECTED.

3082 *** USER WARNING MESSAGE 3082, M = **********, N = **********.

More than one n-set degree-of-freedom is associated with an m-set degree-of-freedom. The set relationship to be used is indicated in the message.

3083 *** USER FATAL MESSAGE 3083, UM PØSITIØN = **********, SIL = **********.

An m-set degree-of-freedom is not expressed in terms of an n-set degree-of-freedom.

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3084 *** USER FATAL MESSAGE 3084, THERE IS NØ TEMPERATURE DATA FØR SIL NUMBER **********.

3085 *** USER FATAL MESSAGE 3085, THE PF LØAD VECTØR IS EITHER PURGED ØR NULL.

3086 (1) *** USER INFØRMATIØN MESSAGE 3086, ENTERING SSGHT EXIT MØDE BY REASØN NUMBER 1 (NØRMAL CØNVERGENCE).

3086 (2) *** USER INFØRMATIØN MESSAGE 3086, ENTERING SSGHT EXIT MØDE BY REASØN NUMBER 2 (MAXIMUM ITERATIØNS).

3086 (3) *** USER INFØRMATIØN MESSAGE 3086, ENTERING SSGHT EXIT MØDE BY REASØN NUMBER 3 (DIVERGING SØLUTIØN).

3086 (4) *** USER INFØRMATIØN MESSAGE 3086, ENTERING SSGHT EXIT MØDE BY REASØN NUMBER 4 (INSUFFICIENT TIME).

3086 (5) *** USER INFØRMATIØN MESSAGE 3086, ENTERING SSGHT EXIT MØDE BY REASØN NUMBER 5 (MAXIMUM CØNVERGENCE).

1. Normal convergence occurs when the solution meets the convergence criteria defined by the parameter EPSHT.
2. Iterations are terminated when the number defined by the parameter MAXIT is attained.
3. Iterations are terminated when the solution diverges.
4. Iterations are terminated when there is insufficient time to complete the next loop.
5. Iterations are terminated when there is no change to the solution vector but the parameter EPSHT criteria was not met.

3087 *** USER FATAL MESSAGE 3087, TEMPERATURE SET ********** IS NØT PRESENT IN GPTT DATA BLØCK.

3088 *** USER FATAL MESSAGE 3088, ILLEGAL GEØMETRY FØR REVØLUTIØN ELEMENT ****.

3089 *** USER FATAL MESSAGE 3089, ILLEGAL GEØMETRY FØR TRIANGLE ELEMENT ****.

3090 *** USER FATAL MESSAGE 3090, ILLEGAL GEØMETR FØR QUAD. ELEMENT ****.

3091 *** SYSTEM WARNING MESSAGE 3091, A TRAPRG ELEMENT = ************** DØES NØT HAVE SIDE 1-2 PARALLEL TØ SIDE 3-4.

3092 *** USER FATAL MESSAGE 3092, TRIARG ØR TRAPRG ELEMENT = ************** PØSSESSES ILLEGAL GEØMETRY.

3093 *** SYSTEM FATAL MESSAGE 3093, ELEMENT = ******** REASØN = ******.

A thermal load (via QVØL card) can not be computed because:

1. Less than 2 points have been referenced. } Rods; triangular or quadrilateral membranes, plates or rings; solid hexahedra.
2. Unable to locate SIL value.
3. Unrecognizable form for element.
4. Illegal number of points for triangular or quadrilaterial membranes, plates or rings.
5. Illegal number of points for solid hexahedra.

3094 *** SYSTEM FATAL MESSAGE 3094, SLT LØAD TYPE ********** IS NØT RECØGNIZED.

3095 *** USER WARNING MESSAGE 3095, ELEMENT TYPE ********** WITH ID = *********, AND APPEARING ØN EITHER A QVECT, QBDY1, QBDY2, ØR QVØL LØAD CARD HAS THE SAME ID AS ELEMENT ØF ANØTHER TYPE AND IS NØT BEING USED FØR LØADING.

3096 *** USER FATAL MESSAGE 3096, ELEMENT ID = ********** AS REFERENCED ØN A QVØL, QBDY1, QBDY2, ØR QVECT LØAD CARD CØULD NØT BE FØUND AMØNG ACCEPTABLE ELEMENTS FØR THAT LØAD TYPE.

3097 (1) *** USER FATAL MESSAGE 3097, CØLUMN ****** IS SINGULAR. UNSYMMETRIC ******** DECØMP ABØRTED.

3097 (2) *** USER FATAL MESSAGE 3097, SYMMETRIC DECØMPØSITIØN ØF DATA BLØCK ******** ABØRTED BECAUSE THE FØLLØWING CØLUMNS ARE SINGULAR --

When a matrix being read in is singular (null column or, for symmetric decomposition, a zero diagonal), the internal column number and type of decomposition is identified. The message does not appear for special cases such as less than three columns or for proportional rows.

3098 *** USER FATAL MESSAGE 3098, QDMEM2 ELEMENT STIFFNESS RØUTINE DETECTS ILLEGAL GEØMETRY FØR ELEMENT ID = **********.

3099 *** USER FATAL MESSAGE 3099, ELEMENT STIFFNESS CØMPUTATIØN FØR QDMEM2 ELEMENT ID = ********** IS IMPØSSIBLE DUE TØ SINGULARITY IN CØNSTRAINT EQUATIØN.

3100 *** USER WARNING MESSAGE 3100, ELEMENT THERMAL LØAD CØMPUTATIØN FØR QDMEM2 ELEMENT ID = ********** FINDS ILLEGAL GEØMETRY THUS NØ LØADS ØUTPUT FØR ELEMENT-ID NØTED.

3101 *** USER WARNING MESSAGE 3101, SINGULARITY ØR BAD GEØMETRY FØR QDMEM2 ELEMENT ID = ********* STRESS ØR FØRCES WILL BE INCØRRECT.

3102 (1) *** SYSTEM FATAL MESSAGE 3102, LØGIC ERRØR EMA- ****.

3102 (2) *** USER WARNING MESSAGE 3102, SUBRØUTINE TRHT1C, UNSTABLE TEMP. VALUE ØF *************** ****, CØMPUTED FØR TIME STEP ***** AT PØINT NUMBER ****** IN THE ANALYSIS STEP.

3103 (1) *** USER WARNING MESSAGE 3103, EMGCØR ØF EMG MØDULE FINDS EITHER ØF DATA BLØCKS **** ØR **** ABSENT AND THUS ****, MATRIX WILL NØT BE FØRMED.

3103 (2) *** USER FATAL MESSAGE 3103, SUBRØUTINE TRHT1C TERMINATING DUE TØ ERRØR CØUNT FØR MESSAGE 3102.

This occurs for 10 errors detected in the temperature computation.

3104 *** SYSTEM WARNING MESSAGE 3104, EMGCØR FINDS SET (ASSUMED DATA BLØCK *****) MISSING. EMG MØDULE CØMPUTATIØNS LIMITED.

3105 *** SYSTEM FATAL MESSAGE 3105, EMGPRØ FINDS ******** ELEMENTS (ELEMENT TYPE ***) UNDEFINED IN EST DATA BLØCK AND/ØR ELEMENT RØUTINE.

3106 *** SYSTEM FATAL MESSAGE 3106, EMGPRØ FINDS THAT ELEMENT TYPE *** HAS EST ENTRIES TØØ LARGE TØ HANDLE CURRENTLY.

3107 *** SYSTEM INFØRMATIØN MESSAGE 3107, EMGØLD CALLED BY EMGPRØ TØ PRØCESS ******** ELEMENTS.

3108 *** SYSTEM FATAL MESSAGE 3108, EMGØUT RECEIVES ILLEGAL FILE TYPE = **********.

3109 *** SYSTEM FATAL MESSAGE 3109, EMGØUT HAS BEEN SENT AN INVALID DICTIØNARY WØRD-2 = ********** FRØM ELEMENT ID = **********.

3110 *** SYSTEM FATAL MESSAGE 3110, EMGØUT HAS BEEN CALLED TØ WRITE AN INCØRRECT NUMBER ØF WØRDS FØR ELEMENT ID = **********.

3111 *** SYSTEM FATAL MESSAGE 3111, INVALID NUMBER ØF PARTITIØNS WERE SENT EMGØUT FØR ELEMENT ID = ********** WITH RESPECT TØ DATA BLØCK TYPE = ***.

3112 *** USER INFØRMATIØN MESSAGE 3112, ELEMENTS CØNGRUENT TØ ELEMENT ID = ********** WILL BE RE-CØMPUTED AS THERE IS INSUFFICIENT CØRE AT THIS MØMENT TØ HØLD DICTIØNARY DATA. ADDITIØNAL CØRE NEEDED = **** WØRDS.

3113 *** SYSTEM INFØRMATIØN MESSAGE 3113, EMGPRØ PRØCESSING ****** PRECISIØN ELEMENTS (ELEMENT

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TYPE ***) STARTING WITH ID ********.

3115 *** USER FATAL MESSAGE 3115, EMGPRØ FINDS ******** ELEMENTS (ELEMENT TYPE ***) PRESENT IN A HEAT FØRMULATIØN.

This includes CCØNEAX, CTØRDRG, CTRAPAX, CTRIAAX, CFLUIDi, CSLØTi, CSHEAR, CTWIST, CTRBSC, CTRPLT, CQDPLT, CMASSi, CØNMi, CAXIFi, CAERØ1, CTRIM6, CTRPLT1 and CTRSHL elements.

3116 *** SYSTEM FATAL MESSAGE 3116, ELEMENT ID ********** SENDS BAD SIL TØ RØUTINE EMG1B.

3117 *** USER WARNING MESSAGE 3117, DIFFERENTIAL STIFFNESS CAPABILITY NØT DEFINED FØR **** ELEMENTS (ELEMENT TYPE ****).

3118 *** USER FATAL MESSAGE 3118, RØD ELEMENT NØ. ********** HAS ILLEGAL GEØMETRY ØR CØNNECTIØNS.

3119 *** USER FATAL MESSAGE 3119, INSUFFICIENT CØRE TØ PRØCESS RØD ELEMENTS.

3120 *** USER WARNING MESSAGE 3120, IMPRØPER CØNNECTIØN ØN CELAS ELEMENT, **********.

3121 *** SYSTEM WARNING MESSAGE 3121, EMGØLD HAS RECEIVED A CALL FØR ELEMENT ID **** (ELEMENT TYPE ********). ELEMENT IGNØRED AS THIS ELEMENT TYPE IS NØT HANDLED BY EMGØLD.

3122 *** SYSTEM FATAL MESSAGE 3122, EMGØUT HAS DETERMINED THAT THERE ARE **** CØNNECTING GRID PØINTS FØR ELEMENT ID = ****. THIS IS GREATER THAN THE MAXIMUM AS PER /GPTA1/ TABLE FØR THE TYPE ØF THIS ELEMENT. PRØBABLE ERRØR IN ELEMENT RØUTINE PRØGRAM.

3123 *** USER FATAL MESSAGE 3123, PARAMETER NUMBER ***** NØT IN DMAP CALL.

3124 *** USER FATAL MESSAGE 3124, PARAMETER NUMBER ***** IS NØT A VARIABLE.

3125 *** SYSTEM FATAL MESSAGE 3125, INVALID TABLE NUMBER. **********, IS NØ. *****, ØF *****, PASSED TØ PRETABLE.

3128 *** SYSTEM WARNING MESSAGE 3128, **** **** AND **** **** ARE EQUIVALENT LABELS. CØNSULT BØTH FØR INTERCHANGEABLE XREF.

3129 *** USER FATAL MESSAGE 3129, SDR3 CAN ØNLY PRØCESS 30 ELEMENT TYPES, PRØBLEM HAS ***.

The total of 30 different element types includes the sum of the different types of structural/scalar elements plus the different types of user's DUMMY elements.

3130 *** SYSTEM FATAL MESSAGE 3130, LØGIC ERRØR ****** ØCCURRED IN SDCØMP.
CØNTENTS ØF /SDCØMX/ FØLLØW --

Numerous error conditions exist in subroutine SDCØMP. The current value in the error message helps the programmer to specifically locate the area of the code where the error occurred. CØMMØN block SDCØMX is dumped in case DIAG 1 was not on.

3131 *** USER FATAL MESSAGE 3131, INPUT STIFFNESS AND MASS MATRICES ARE NØT CØMPATIBLE.

The matrices must be of the same size in order to properly perform matrix operations.

3132 *** SSGHT RECØVERING FRØM SEVERE USER CØNVERGENCE CRITERIA.

A nonlinear heat transfer solution cannot converge because the value for EPSHT on a PARAM card is too small. Either change the value to one which requires less accuracy or provide for a greater number of iterations (MAXIT on another PARAM card) to allow the solution to converge.

3133 *** USER FATAL MESSAGE 3133, LENGTH ØF CRIGDR (RIGID RØD) ELEMENT ******** IS ZERØ.

The end grid points of the element cannot be coincident.

3134 *** USER FATAL MESSAGE 3134, CRIGDR (RIGID RØD) ELEMENT ******** IS NØT PRØPERLY DEFINED.

The direction defined by the dependent translational degree of freedom cannot be perpendicular (or nearly perpendicular) to the element.

3135 *** USER FATAL MESSAGE 3135, UNABLE TØ PRØCESS SEQGP DATA IN SUBRØUTINE GP1 DUE TØ INSUFFICIENT CØRE. ADDITIØNAL CØRE REQUIRED = **** WØRDS.

3136 *** USER FATAL MESSAGE 3136, MULTIPLE REFERENCES TØ GRID (ØR SCALAR) PØINT ID NØ. **** ØN SEQGP CARDS.

3137 *** USER FATAL MESSAGE 3137, MULTIPLE REFERENCES TØ SEQUENCE ID NØ. **** ØN SEQGP CARDS.

3138 *** USER FATAL MESSAGE 3138, SEQUENCE ID NØ. **** ØN SEQGP CARDS IS THE SAME AS A GRID (ØR SCALAR) PØINT ID NØ. THAT HAS NØT BEEN RESEQUENCED.

3139 *** USER FATAL MESSAGE 3139, UNABLE TØ PRØCESS SEQEP DATA IN SUBRØUTINE DPD1 DUE TØ INSUFFICIENT CØRE. ADDITIØNAL CØRE REQUIRED = **** WØRDS.

3140 *** USER FATAL MESSAGE 3140, MULTIPLE REFERENCES TØ EXTRA PØINT ID NØ. **** ØN SEQEP CARDS.

3141 *** USER FATAL MESSAGE 3141, MULTIPLE REFERENCES TØ SEQUENCE ID NØ. **** ØN SEQEP CARDS.

3142 *** USER FATAL MESSAGE 3142, SEQUENCE ID NØ. **** ØN SEQEP CARDS IS THE SAME AS AN EXTRA PØINT ID NØ. THAT HAS NØT BEEN RESEQUENCED.

3143 *** USER INFØRMATIØN MESSAGE 3143, THE EIGENVALUES AND EIGENVECTØRS FØUND ØN THIS RESTART WILL BE APPENDED TØ THE ******** EIGENVALUES AND EIGENVECTØRS PREVIØUSLY CHECKPØINTED.

This message is generated when the APPEND feature is being used in the case of the Determinant, Inverse Power and FEER methods of real eigenvalue extraction. (See Section 3.4.7).

3144 *** USER WARNING MESSAGE 3144, EMGPRØ FINDS ******** ELEMENTS (ELEMENT TYPE ***) PRESENT IN A HEAT FØRMULATIØN AND IS REPLACING THE SAME BY ******** ELEMENTS (ELEMENT TYPE ***).

In a HEAT formulation, element types CQDMEM1 and CQDMEM2 are automatically replaced by element type CQDMEM.

3145 *** USER FATAL MESSAGE 3145, CØMPØNENT 0 (ØR BLANK) SPECIFIED FØR GRID PØINT ******** ØN ******** CARDS.

3146 *** USER FATAL MESSAGE 3146, NØN-ZERØ CØMPØNENT SPECIFIED FØR SCALAR PØINT ******** ØN ******** CARDS.

3147 *** USER FATAL MESSAGE 3147, ENFØRCED DISPLACEMENT ØN SPC CARDS SPECIFIED MØRE THAN ØNCE FØR THE SAME CØMPØNENT. SIL VALUE = ********.

The use of DIAG 21 in the Executive Control Deck will show the SIL (internal DØF) corresponding to the duplicated component.

3148 *** USER FATAL MESSAGE 3148, CRIGD3 (GENERAL RIGID) ELEMENT ******** IS NØT PRØPERLY DEFINED.

The six reference degrees of freedom selected for the element must together represent six independent components of motion.

3149 *** USER WARNING MESSAGE 3149, USER SPECIFIED NEIGHBØRHØØD CENTERED AT ØRIGIN NØT ALLØWED, CENTER SHIFTED TØ THE RIGHT .001.

Point of interest in the complex plane (α_{ai}, ω_{ai}), closest to which the eigenvalues will be computed, was input as (0.0, 0.0) on an EIGC bulk data continuation card. The point automatically used is (.001, 0.0).

3150 *** USER WARNING MESSAGE 3150, DESIRED NUMBER ØF EIGENVALUES ******** INVALID. SET = 1.

Number of accurate roots desired, N_{d1}, was omitted, input as zero, or negative on an EIGC bulk data continuation card. The number automatically used is 1.

3151 *** USER WARNING MESSAGE 3151, DYNAMIC MATRIX IS SINGULAR (ØCCURRENCE **) IN NEIGHBØRHØØD CENTERED AT ******** ********.

Point of interest in the complex plane (α_{ai}, ω_{ai}), closest to which the eigenvalues will be computed, was input too close to an eigenvalue on an EIGC bulk data continuation card. The point is automatically shifted by adding .02 to both the real and imaginary parts. If the dynamic matrix is still singular, the next neighborhood, if any, is searched.

3152 *** USER INFØRMATIØN MESSAGE 3152, SUBRØUTINE ALLMAT ØUTPUT EIGENVALUE **** IS NULL.

When an eigenvalue output from subroutine ALLMAT is exactly zero, the formula for computing the associated theoretical error test fails. The magnitude of the eigenvalue is considered to be 10^{-10} for use in that formula.

3153 *** USER WARNING MESSAGE 3153, ATTEMPT TØ NØRMALIZE NULL VECTØR IN SUBRØUTINE CFEER4. NØ ACTIØN TAKEN.

An eigenvector output from subroutine ALLMAT is a zero vector.

3154 *** USER WARNING MESSAGE 3154, SIZE ØF REDUCED PRØBLEM DECREMENTED ØNCE (NØW ****) DUE TØ NULL ERRØR ELEMENT.

If subroutine CFEER4 receives a reduced tridiagonal matrix having error element d_{m+1} exactly (0,0), it is impossible to compute meaningful theoretical error estimates for any of the eigenvalues. The size of the reduced problem is reduced by one, so that d_m becomes the new error element.

3155 *** USER WARNING MESSAGE 3155, REDUCED PRØBLEM HAS VANISHED. NØ RØØTS FØUND.

If decrementing the size of the reduced problem (see message 3154) causes the size to become zero, the program continues to the next neighborhood, if any.

3156 *** USER WARNING MESSAGE 3156, SIZE ØF REDUCED PRØBLEM RESTØRED TØ **** BECAUSE NEXT ERRØR ELEMENT WAS ALSØ NULL. ERRØR ELEMENT SET = **** ****.

This message follows message 3154. If d_m is also exactly zero (in addition to d_{m+1} being exactly zero), then the original reduced problem size is restored and d_{m+1} is set to (ε, 0) where ε = E/100 and E is the error tolerance on acceptable eigenvalues input on the EIGC bulk data card.

3157 *** USER WARNING MESSAGE 3157, FEER PRØCESS MAY HAVE CALCULATED FEWER ACCURATE MØDES **** THAN REQUESTED IN THE NEIGHBØRHØØD ØF **** ****.

The desired number of eigenvalues specified in the EIGC bulk data continuation card exceeds the additional number that can be calculated by the Complex Tridiagonal Reduction (Complex FEER) method in the current neighborhood.

3158 *** USER WARNING MESSAGE 3158, NØ ADDITIØNAL MØDES CAN BE FØUND BY FEER IN THE NEIGHBØRHØØD ØF **** ****.

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An initial pseudo-random vector cannot be made orthogonal to the existing set of orthogonal vectors (which come from Restart and from all prior-neighborhood sets of eigensolutions).

3159 *** USER INFØRMATIØN MESSAGE 3159, ALL SØLUTIØNS HAVE BEEN FØUND.

The FEER method has solved the entire problem. Any additional neighborhoods (as specified by the presence of EIGC bulk data continuation cards) are ignored.

3160 *** USER INFØRMATIØN MESSAGE 3160, MINIMUM ØPEN CØRE NØT USED BY FEER ********** WØRDS (********** K BYTES).

This message indicates the amount of open core, in both bytes and words, not used by FEER.

3161 *** USER WARNING MESSAGE 3161, DESIRED NUMBER ØF EIGENSØLUTIØNS ***** FØR NEIGHBØRHØØD *** ØF *** CENTERED AT ******** ******** EXCEEDS THE EXISTING NUMBER *****, ALL EIGENSØLUTIØNS WILL BE SØUGHT.

The desired number of eigenvalues specified on the EIGC bulk data continuation card exceeds the size of the eigenmatrix, which is the maximum possible number of existing eigenvalues.

3162 *** USER WARNING MESSAGE 3162, ATTEMPT TØ NØRMALIZE NULL VECTØR. NØ ACTIØN TAKEN.

The general vector normalization routine (CFNØR1 or CFNØR2) has a zero vector input to it.

3163 *** USER WARNING MESSAGE 3163, ALL **** SØLUTIØNS HAVE FAILED ACCURACY TEST. NØ RØØTS FØUND.

The number of eigensolutions passing the relative error test is zero. The maximum allowable error for the relative error test is specified in field 7 of the EIGC bulk data card. A detailed list of the computed error bounds could have been obtained by requesting DIAG 12 in the Executive Control Deck.

3164 *** USER INFØRMATIØN MESSAGE 3164, ALL **** SØLUTIØNS ARE ACCEPTABLE.

All the eigensolutions obtained in the reduced problem corresponding to the point of interest pass the relative error test. The maximum allowable error for the relative error test is specified in field 7 of the EIGC bulk data card. A detailed list of the computed error estimates could have been obtained by requesting DIAG 12 in the Executive Control Deck.

3165 *** USER INFØRMATIØN MESSAGE 3165, **** SØLUTIØNS HAVE BEEN ACCEPTED AND **** SØLUTIØNS HAVE BEEN REJECTED.

In each neighborhood defined by a center, some eigensolutions passed the relative error test and some did not.

3166 *** USER INFØRMATIØN MESSAGE 3166, ***** MØRE ACCURATE EIGENSØLUTIØNS THAN THE ***** REQUESTED HAVE BEEN FØUND FØR NEIGHBØRHØØD *** ØF *** CENTERED AT ******** ********. USE DIAG 12 TØ DETERMINE ERRØR ESTIMATES.

The number of eigensolutions passing the relative error test is greater than the number requested on the corresponding EIGC bulk data continuation card. The maximum allowable error for the relative error test is specified in field 7 of the EIGC bulk data card. A detailed list of the computed error estimates could have been obtained by requesting DIAG 12 in the Executive Control Deck.

3169 *** USER WARNING MESSAGE 3169, PRIMARY ID ******** ØN A CNGRNT CARD ALSØ USED AS A SECØNDARY ID ØN THE SAME CARD. SECØNDARY ID IGNØRED.

3170 *** USER FATAL MESSAGE 3170, PRIMARY ID ******** ØN A CNGRNT CARD ALSØ USED AS A SECØNDARY ID

ØN ANØTHER CNGRNT CARD.

3171 *** USER FATAL MESSAGE 3171, SECØNDARY ID ******** SPECIFIED AS CØNGRUENT TØ MØRE THAN ØNE PRIMARY ID.

3172 *** USER WARNING MESSAGE 3172, SECØNDARY ID ******** REDUNDANTLY SPECIFIED ØN CNGRNT CARDS. REDUNDANCIES IGNØRED.

3173 *** USER WARNING MESSAGE 3173, NØ NØN-ZERØ MATERIAL CØØRDINATE SYSTEM IDS ENCØUNTERED IN MØDULE CURV. $\left\{\begin{matrix}\text{STRESSES}\\ \text{STRAINS/CURVATURES}\end{matrix}\right\}$ IN MATERIAL CØØRDINATE SYSTEM NØT CØMPUTED.

Stresses or strains/curvatures are computed in module CURV only if non-zero material coordinate system ids are specified.

3174 *** SYSTEM FATAL MESSAGE 3174, SUBRØUTINE CURV* HAS RETURNED WITH ERRØR CØNDITIØN ***.
LØCATIØN CØDE = *** IN SUBRØUTINE CURV*
FILE NUMBER = ***

The information supplied by the message should enable a programmer to investigate the cause of the error.

3175 *** USER FATAL MESSAGE 3175, TØTAL NUMBER ØF DEGREES ØF FREEDØM IN THE PRØBLEM (****) EXCEEDS 65535.

3176 *** USER FATAL MESSAGE 3176, BAR ELEMENT NØ. **** HAS ILLEGAL GEØMETRY ØR CØNNECTIØNS.

3178 *** USER FATAL MESSAGE 3178, LØAD SET **** NØT FØUND. REQUIRED FØR DEFINITIØN ØF CØMBINATIØN LØAD ****.

3179 *** USER FATAL MESSAGE 3179, DUPLICATE LØAD SET **** FØUND IN DEFINITIØN ØF CØMBINATIØN LØAD ****.

3180 *** USER FATAL MESSAGE 3180, INDEPENDENT CØMPØNENT SPECIFIED MØRE THAN ØNCE IN AN MPC RELATIØNSHIP. SIL VALUE = ****.

3181 *** USER FATAL MESSAGE 3181, ATTEMPT TØ PERFØRM CHØLESKY DECØMPØSITIØN ØN A NEGATIVE DEFINITE MATRIX IN SUBRØUTINE SDCØMP.

3182 *** USER WARNING MESSAGE 3182, INSUFFICIENT CØRE TØ PRØCESS ALL CNGRNT CARDS. ADDITIØNAL CØRE NEEDED = **** WØRDS.

3199 *** USER WARNING MESSAGE 3199, NØN-FATAL MESSAGES MAY HAVE BEEN LØST BY ATTEMPTING TØ QUEUE MØRE THAN ***** MESSAGES.

3300 *** SYSTEM WARNING MESSAGE 3300, INVALID PARAMETER **** **** SUPPLIED TØ MØDULE DIAGØNAL, CØLUMN SUBSTITUTED.

3301 *** USER FATAL MESSAGE 3301, IHEX* ELEMENT NUMBER ******** INSUFFICIENT CØRE TØ CØMPUTE ELEMENT MATRIX.

3302 *** USER FATAL MESSAGE 3302, IHEX* ELEMENT NUMBER ******** ILLEGAL GEØMETRY, text.

The type of geometry error is identified in "text". The possibilities are:

AR EXCEEDED ALFA EXCEEDED BETA EXCEEDED	Either correct the element or increase the allowable value on the PIHEX card for this element.
REVERSED NUMBERING	The element was numbered in a clockwise fashion rather

than counter-clockwise as required. This would result in a left-handed element coordinate system. Correct the numbering sequence on the CIHEXi card for this element.

CØØRDINATES ØF TWØ PØINTS ARE THE SAME	The coordinates of all of the connected points of the element must be different.

3303 *** USER FATAL MESSAGE 3303, STRESSES REQUESTED FØR SET *** WHICH CØNTAINS NØ VALID ELEMENT ID-S.

The set of elements for which stresses were requested in this subcase contains only IDs for nonexistent elements.

3304 *** USER FATAL MESSAGE 3304, PLØAD3 CARD FRØM LØAD SET ******** REFERENCES MISSING ØR NØN-ISØPARAMETRIC ELEMENT ********.

3305 *** USER FATAL MESSAGE 3305, PLØAD3 CARD FRØM LØAD SET ******** HAS INVALID GRID PØINT NUMBERS FØR ELEMENT ********.

Either the element does not connect the specified grid points, or the grid points do not identify the diagonal of a face of the element.

3306 *** USER FATAL MESSAGE 3306, SINGULAR JACØBIAN MATRIX FØR ISØPARAMETRIC ELEMENT NUMBER ********.

The element is severely warped or the outer surface of the element is folded through itself. Check the connection card for this element and the coordinates of the points it connects.

4000 *** USER WARNING MESSAGE 4000, ØNE SIDE ØF ELEMENT ******** CØNNECTING FØUR PØINTS IS NØT APPRØXIMATELY PLANAR.

Check CWEDGE and CHEXAi cards for order of grid point identification numbers, or incorrect grid point identification numbers.

6.6 FUNCTIONAL MODULE MESSAGES (4001 THRU 5000)

4001 *** USER FATAL MESSAGE 4001, ELEMENT ******** DØES NØT HAVE CØRRECT GEØMETRY.

4002 *** USER FATAL MESSAGE 4002, MØDULE SSG1 DETECTS BAD ØR REVERSED GEØMETRY FØR ELEMENT ID ********.

Check CWEDGE and CHEXAi cards for order of grid point identification numbers or incorrect grid point identification numbers. Subtetrahedra must have nonzero volume.

4003 *** USER FATAL MESSAGE 4003, AN ILLEGAL VALUE ØF -NU- HAS BEEN SPECIFIED UNDER MATERIAL ID ******** FØR ELEMENT ID ********.

Solid WEDGE and HEXAi elements must not have Poisson's ratio equal to 0.5.

4004 *** USER FATAL MESSAGE 4004, MØDULE SMA1 DETECTS BAD ØR REVERSED GEØMETRY FØR ELEMENT ID ********.

Check CWEDGE and CHEXAi cards for order of grid point identification numbers, or incorrect grid point identification numbers. Subtetrahedra must have nonzero volume.

4005 *** USER FATAL MESSAGE 4005, AN ILLEGAL VALUE ØF -NU- HAS BEEN SPECIFIED UNDER MATERIAL ID ******** FØR ELEMENT ID ********.

Solid TETRA elements must not have Poisson's ratio equal to 0.5.

4010 *** USER FATAL MESSAGE 4010, TEMPP3 BULK DATA CARD WITH SETID = ******** AND ELEMENT ID = ******** DØES NØT HAVE ASCENDING VALUES SPECIFIED FØR Z.

4011 *** USER FATAL MESSAGE 4011, ELEMENT TEMPERATURE SET ******** CØNTAINS MULTIPLE TEMPERATURE DATA SPECIFIED FØR ELEMENT ID ********.

Temperature for element is specified on more than one bulk data card.

4012 *** USER FATAL MESSAGE 4012, THERE IS NØ ELEMENT, GRID PØINT, ØR DEFAULT TEMPERATURE DATA FØR TEMPERATURE SET ******** WITH RESPECT TØ ELEMENT ********.

4013 *** USER FATAL MESSAGE 4013, PRØBLEM LIMITATIØN ØF 66 TEMPERATURE SETS HAS BEEN EXCEEDED.

4014 *** SYSTEM FATAL MESSAGE 4014, RØUTINE EDTL DETECTS BAD DATA ØN TEMPERATURE DATA BLØCK FØR SET ID = ********.

Data block GPTT should be investigated.

4015 *** SYSTEM WARNING MESSAGE 4015, ELEMENT THERMAL AND DEFØRMATIØN LØADING NØT CØMPUTED FØR ILLEGAL ELEMENT TYPE ******** IN MØDULE SSG1.

Ønly certain elements have algorithms for enforced deformation or thermal loading. This element type will not produce a load. Check DEFØRM and TEMPP1, TEMPP2, TEMPP3 and TEMPRB bulk data cards.

4016 *** USER FATAL MESSAGE 4016, THERE IS NØ TEMPERATURE DATA FØR ELEMENT ******** IN SET ********.

4017 *** USER FATAL MESSAGE 4017, THERE IS NØ TEMPERATURE DATA FØR ELEMENT ******** IN SET ********.

4018 *** USER FATAL MESSAGE 4018, A SINGULAR MATERIAL MATRIX -D- FØR ELEMENT ******** HAS BEEN DETECTED BY RØUTINE SSGKHI WHILE TRYING TØ CØMPUTE THERMAL LØADS WITH TEMPP2 CARD DATA.

The element bending load - curvature relation is at fault and cannot be inverted.

1530

4019 *** SYSTEM FATAL MESSAGE 4019, SDR2E DETECTS INVALID TEMPERATURE DATA FØR ********.

Data block GPTT should be investigated.

4020 *** SYSTEM FATAL MESSAGE 4020, TA1A HAS PICKED UP TEMPERATURE SET ******** AND NØT THE REQUESTED SET ********.

The requested temperature set ID for temperature-dependent material properties cannot be found in data block GPTT.

4021 *** SYSTEM FATAL MESSAGE 4021, TA1B HAS PICKED UP TEMPERATURE SET ******** AND NØT THE REQUESTED SET ********.

The requested temperature set ID for temperature-dependent material properties cannot be found in data block GPTT.

4022 *** USER FATAL MESSAGE 4022, TA1B FINDS NØ ELEMENT, GRIDPØINT, ØR DEFAULT TEMPERATURE DATA FØR ELEMENT ID = ********.

4023 *** USER FATAL MESSAGE 4023, TA1A FINDS NØ ELEMENT, GRIDPØINT, ØR DEFAULT TEMPERATURE DATA FØR ELEMENT ID = ********.

4024 *** USER FATAL MESSAGE 4024, NØ CYJØIN CARDS WERE SUPPLIED.

4025 *** USER FATAL MESSAGE 4025, NØ SIDE 1 DATA FØUND.

4026 *** USER FATAL MESSAGE 4026, TØØ MANY SIDE 1 CARDS.

4027 *** USER FATAL MESSAGE 4027, NUMBER ØF ENTRIES IN SIDE 1 NØT EQUAL TØ NUMBER IN SIDE 2.

4028 *** USER FATAL MESSAGE 4028, THE CØDE FØR GRID PØINT, ********** DØES NØT MATCH THE CØDE FØR GRID PØINT **********.

A GRID point on SIDE 1 must be connected to a GRID point on SIDE 2 and a SCALAR point on SIDE 1 must be connected to a SCALAR point on SIDE 2.

4029 *** USER FATAL MESSAGE 4029, GRID PØINT, ********** APPEARS IN BØTH SIDE LISTS.

4030 *** USER WARNING MESSAGE 4030, CØMPØNENT *** ØF GRID PØINTS, ********** AND ********** CANNØT BE CØNNECTED.

4031 *** USER FATAL MESSAGE 4031, INSUFFICIENT CØRE = **** TØ READ DATA ØN AXIF CARD.

4032 *** USER WARNING MESSAGE 4032, NØ CØMPØNENTS ØF GRID PØINTS, ********** AND ********** WERE CØNNECTED.

4033 *** USER FATAL MESSAGE 4033, CØØRDINATE SYSTEM ID = **** AS SPECIFIED ØN AXIF CARD IS NØT PRESENT AMØNG ANY ØF CØRD1C, CØRD2C, ØR CØRD2S CARD TYPES.

Cylindrical type assumed for continuing data check.

4034 *** USER FATAL MESSAGE 4034, INSUFFICIENT CØRE TØ HØLD GRIDB CARD IMAGES. ADDITIØNAL CØRE NEEDED = **** WØRDS.

4035 *** USER FATAL MESSAGE 4035, THE FLUID DENSITY HAS NØT BEEN SPECIFIED ØN A BDYLIST CARD AND THERE IS NØ DEFAULT FLUID DENSITY SPECIFIED ØN THE AXIF CARD.

4036 *** USER FATAL MESSAGE 4036, INSUFFICIENT CØRE TØ BUILD BØUNDARY LIST TABLE.

4037 *** USER FATAL MESSAGE 4037, GRID PØINT ********** IS LISTED MØRE THAN ØNCE.

4038 *** USER FATAL MESSAGE 4038, RINGFL CARD HAS ID = **** WHICH HAS BEEN USED.

An identification number of a RINGFL card is not unique.

4039 *** USER FATAL MESSAGE 4039, NØ CØØRDINATE SYSTEM DEFINED FØR GRID PØINT **********.

4040 *** USER FATAL MESSAGE 4040, ID = **** APPEARS ØN A BDYLIST CARD, BUT NØ RINGFL CARD IS PRESENT WITH THE SAME ID.

4041 *** USER FATAL MESSAGE 4041, ID = **** IS ØUT ØF PERMISSIBLE RANGE ØF 1 TØ 499999.

The identification number of a RINGFL card is too large to be processed.

4042 *** USER FATAL MESSAGE 4042, CØØRDINATE SYSTEM IS CYLINDRICAL BUT RINGFL CARD ID = **** HAS A NØNZERØ X2 VALUE.

The azimuthal angle of a RINGFL point must be zero.

4043 *** USER FATAL MESSAGE 4043, CØØRDINATE SYSTEM IS SPHERICAL BUT RINGFL CARD ID = **** HAS A NØNZERØ X3 VALUE.

The azimuthal angle of a RINGFL point must be zero.

4044 *** USER FATAL MESSAGE 4044, RINGFL CARD ID = **** HAS SPECIFIED A ZERØ RADIAL LØCATIØN.

4045 *** USER FATAL MESSAGE 4045, THE BØUNDARY LIST ENTRY FØR ID = **** HAS A ZERØ CRØSS-SECTIØNAL LENGTH.

A hydroelastic boundary cannot be defined between two RINGFL points having the same location. Check BDYLIST and RINGFL.

4047 *** USER FATAL MESSAGE 4047, INSUFFICIENT CØRE TØ HØLD RINGFL IMAGES. ADDITIØNAL CØRE NEEDED = **** WØRDS.

4048 *** USER FATAL MESSAGE 4048, THE FLUID DENSITY HAS NØT BEEN SPECIFIED ØN A FSLIST CARD AND THERE IS NØ DEFAULT FLUID DENSITY SPECIFIED ØN THE AXIF CARD.

4049 *** USER FATAL MESSAGE 4049, INSUFFICIENT CØRE TØ BUILD FREE SURFACE LIST TABLE. ADDITIØNAL CØRE NEEDED = **** WØRDS.

4050 *** USER FATAL MESSAGE 4050, FSLIST CARD HAS INSUFFICIENT IDF DATA, ØR FSLIST DATA MISSING.

A referenced RINGFL point does not exist or the FSLIST card is in error. At least two points must be defined.

4051 *** USER FATAL MESSAGE 4051, AN MPC CARD HAS A SET ID SPECIFIED = 102. SET 102 IS ILLEGAL WHEN FLUID DATA IS PRESENT.

This set identification number is reserved for internal use in hydroelastic problems.

4052 *** USER FATAL MESSAGE 4052, IDF = **** ØN A FREEPT CARD DØES NØT APPEAR ØN ANY FSLIST CARD.

A referenced RINFGL point must also appear on a FSLIST card.

4053 *** USER FATAL MESSAGE 4053, INSUFFICIENT CØRE TØ PERFØRM ØPERATIØNS REQUIRED AS A RESULT ØF FREEPT ØR PRESPT DATA CARDS. ADDITIØNAL CØRE NEEDED = **** WØRDS.

4054 *** USER WARNING MESSAGE 4054, STRESSES ØR FØRCES REQUESTED FØR SET(S) WHICH CØNTAIN NØ VALID ELEMENTS.

Stress or force output requests are not valid for fluid elements.

4055 *** USER FATAL MESSAGE 4055, SET ID = 102 MAY NØT BE USED FØR SPC CARDS WHEN USING THE HYDRØELASTIC-FLUID ELEMENTS.

This set identification number is reserved for internal use in hydroelastic problems.

4056 *** USER FATAL MESSAGE 4056, RECØRD ID **** **** IS ØUT ØF SYNC ØN DATA BLØCK NUMBER **** AN IFP4 SYSTEM ERRØR.

The record identification numbers are the values of LØCATE record ID. The data block numbers are the GINØ file numbers. Error implies that IFP4 is possibly operating on the wrong data block. This system error should not occur. Message comes from IFP4B.

4057 *** USER FATAL MESSAGE 4057, GRIDB CARD WITH ID = **** HAS A REFERENCE IDF = **** WHICH DØES NØT APPEAR IN A BØUNDARY LIST.

4058 *** USER FATAL MESSAGE 4058, THE FLUID DENSITY HAS NØT BEEN SPECIFIED ØN A CFLUID CARD WITH ID = *** AND THERE IS NØ DEFAULT ØN THE AXIF CARD.

4059 *** USER FATAL MESSAGE 4059, THE FLUID BULK MØDULUS HAS NØT BEEN SPECIFIED ØN A CFLUID CARD WITH ID = **** AND THERE IS NØ DEFAULT ØN THE AXIF CARD.

4060 *** SYSTEM FATAL MESSAGE 4060, CØØRDINATE SYSTEM = **** CAN NØT BE FØUND IN CSTM DATA.

Data blocks MATPØØL and/or CSTM have been changed illegally.

4061 *** SYSTEM FATAL MESSAGE 4061, CØNNECTED FLUID PØINT ID = **** IS MISSING BGPDT DATA.

Data blocks MATPØØL and/or BGPDT have been changed illegally.

4062 *** USER FATAL MESSAGE 4062, DMIG BULK DATA CARD SPECIFIES DATA BLØCK **** WHICH ALSØ APPEARS ØN A DMIAX CARD.

A direct input matrix may not be specified by both types of bulk data cards.

4063 *** USER FATAL MESSAGE 4063, ILLEGAL VALUE **** FØR PARAMETER CTYPE.

4064 *** USER FATAL MESSAGE 4064, ILLEGAL VALUES ******** FØR PARAMETERS NSEGS, KMAX.

4065 *** USER FATAL MESSAGE 4065, ILLEGAL VALUE ******** FØR PARAMETER NLØAD.

4066 *** USER FATAL MESSAGE 4066, SECØND ØUTPUT DATA BLØCK MUST NØT BE PURGED.

The transformation matrix between physical and symmetric components does not exist. Ensure that the Case Control subcases are specified correctly and that the component loads are properly ordered.

4067 *** USER FATAL MESSAGE 4067, VIN HAS ******** CØLS, GCYC HAS ******** RØWS.

Follows message 4064 or 4065 indicating illegal values for NSEGS, KMAX or NLOAD. VIN is the first input data block.

4081 *** USER FATAL MESSAGE 4081, AXSLØT DATA CARD IS NØT PRESENT ØR IS INCØRRECT.

Acoustic analysis data is present and this data card is necessary.

4082 *** USER FATAL MESSAGE 4082, INSUFFICIENT CØRE TØ HØLD ALL GRIDS CARD IMAGES.

Executive Module IFP5 must hold this data in core. Increase core size or decrease amount of data.

4083 *** USER FATAL MESSAGE 4083, INSUFFICIENT CØRE TØ HØLD ALL GRIDF CARD IMAGES.

Executive Module IFP5 must hold this data in core. Increase core size or decrease amount of data.

4084 *** USER FATAL MESSAGE 4084, INSUFFICIENT CØRE TØ HØLD ALL GRIDF CARD IMAGES BEING CREATED INTERNALLY DUE TØ GRIDS CARDS SPECIFYING AN IDF.

Executive Module IFP5 is creating GRIDF cards from GRIDS cards. Increase core size.

4085 *** USER FATAL MESSAGE 4085, INSUFFICIENT CØRE TØ CØNSTRUCT ENTIRE BØUNDARY TABLE FØR SLBDY DATA CARDS.

Executive Module IFP5 requires five words of core for each entry in the SLBDY cards.

4086 *** USER FATAL MESSAGE 4086, CELAS2 DATA CARD HAS ID = XXX WHICH IS GREATER THAN 10000000, AND 10000000 IS THE LIMIT FØR CELAS2 ID WITH ACØUSTIC ANALYSIS DATA CARDS PRESENT.

Executive Module IFP5 is generating CELAS2 images and a possible conflict of ID numbers exists.

4087 *** USER FATAL MESSAGE 4087, SLBDY ID = XXX DØES NØT APPEAR ØN ANY GRIDS DATA CARD.

The SLBDY data card has a point listed which does not exist in the data.

4088 *** USER FATAL MESSAGE 4088, ØNE ØR MØRE ØF THE FØLLØWING ID-S NØT EQUAL TØ -1 HAVE INCØRRECT ØR NØ GEØMETRY DATA. ID = XXX, ID = XXX, ID = XXX.

The listed GRIDS points may have a bad radius or a slot width greater than geometrically possible.

4089 *** USER FATAL MESSAGE 4089, RHØ AS SPECIFIED ØN SLBDY ØR AXSLØT DATA CARD IS 0.0 FØR ID = XXX.

A value of density is required to formulate the slot boundary matrix terms.

4090 *** USER FATAL MESSAGE 4090, ØNE ØF THE FØLLØWING NØN-ZERØ IDENTIFICATIØN NUMBERS APPEARS ØN SØME CØMBINATIØN GRID, GRIDS, ØR GRIDF BULK DATA CARDS. ID = XXX, ID = XXX, ID = XXX.

All GRID, SPØINT, EPØINT, GRIDS and GRIDF data cards should have unique identification numbers.

4091 *** USER FATAL MESSAGE 4091, BAD GEØMETRY ØR ZERØ CØEFFICIENT FØR SLØT ELEMENT NUMBER XXX.

The listed CSLØT3 or CSLØT4 element has its connected points defining zero area or its density equal to zero.

4100 *** SYSTEM FATAL MESSAGE 4100, ØUTPUT3 UNABLE TØ ØPEN DATA BLØCK ********.

4101 *** SYSTEM FATAL MESSAGE 4101, ØUTPUT3 UNABLE TØ FIND NAME FØR DATA BLØCK ******************.

4102 *** SYSTEM FATAL MESSAGE 4102, ØUTPUT3 EØF.

4103 *** USER INFØRMATIØN MESSAGE 4103, ØUTPUT3 HAS PUNCHED MATRIX DATA BLØCK ******** ØNTØ DMI CARDS.

4104 *** USER FATAL MESSAGE 4104, ATTEMPT TØ PUNCH MØRE THAN 99999 DMI CARDS FØR A SINGLE MATRIX.

4105 *** USER INFØRMATIØN MESSAGE 4105, DATA BLØCK ******** RETRIEVED FRØM $\left\{\begin{matrix}\text{USER}\\\text{FØRTRAN}\end{matrix}\right\}$ TAPE ****

NAME ØF DATA BLØCK WHEN PLACED ØN $\left\{\begin{matrix}\text{USER}\\\text{FØRTRAN}\end{matrix}\right\}$ TAPE WAS ********.

4106 *** SYSTEM FATAL MESSAGE 4106, MØDULE INPUTT1 - SHØRT REC.

4107 *** SYSTEM FATAL MESSAGE 4107, SUBRØUTINE INPTT1 UNABLE TØ ØPEN NASTRAN FILE ****.

4108 *** SYSTEM FATAL MESSAGE 4108, SUBRØUTINE $\begin{Bmatrix}\text{INPTT1}\\ \text{INPTT2}\end{Bmatrix}$ UNABLE TØ ØPEN ØUTPUT DATA BLØCK ****.

4109 *** USER FATAL MESSAGE 4109, TAPE **** CANNØT BE SWITCHED. FILE **** IS NØT A TAPE.

4111 *** USER FATAL MESSAGE 4111, MØDULE INPUTT1 IS UNABLE TØ SKIP FØRWARD ********** DATA BLØCKS ØN PERMANENT NASTRAN FILE **** NUMBER ØF DATA BLØCKS SKIPPED = *****.

4112 *** USER FATAL MESSAGE 4112, MØDULE INPUTT1 - ILLEGAL VALUE FØR SECØND PARAMETER = *******************.

4113 *** USER FATAL MESSAGE 4113, MØDULE $\begin{Bmatrix}\text{INPUTT1}\\ \text{INPUTT2}\end{Bmatrix}$ - ILLEGAL VALUE FØR FIRST PARAMETER = *******************.

4114 *** USER INFØRMATIØN MESSAGE 4114, DATA BLØCK ******** WRITTEN ØN $\begin{Bmatrix}\text{NASTRAN FILE}\\ \text{FØRTRAN UNIT}\end{Bmatrix}$ ****, TRLR = ************.

4115 *** SYSTEM FATAL MESSAGE 4115, MØDULE $\begin{Bmatrix}\text{ØUTPUT1}\\ \text{ØUTPUT2}\end{Bmatrix}$ - SHØRT REC.

4117 *** SYSTEM FATAL MESSAGE 4117, SUBRØUTINE ØUTPT1 UNABLE TØ ØPEN NASTRAN FILE ****.

4118 *** USER FATAL MESSAGE 4118, ***** MØDULE ØUTPUT1 IS UNABLE TØ SKIP FØRWARD ********** DATA BLØCKS ØN PERMANENT NASTRAN FILE ****. **** NUMBER ØF DATA BLØCKS SKIPPED = *****.

4119 *** USER FATAL MESSAGE 4119, MØDULE ØUTPUT1 - ILLEGAL VALUE FØR SECØND PARAMETER = *******************.

4120 *** USER FATAL MESSAGE 4120, MØDULE $\begin{Bmatrix}\text{ØUTPUT1}\\ \text{ØUTPUT2}\end{Bmatrix}$ - ILLEGAL VALUE FØR FIRST PARAMETER = *******************.

4121 *** USER FATAL MESSAGE 4121, ØNLY ØNE (1) AXIF CARD ALLØWED IN BULK DATA.

4122 *** USER FATAL MESSAGE 4122, AXIF CARD REQUIRED.

4123 *** USER FATAL MESSAGE 4123, ØNLY ØNE (1) FLSYM CARD ALLØWED IN BULK DATA.

4124 *** USER WARNING MESSAGE 4124, THE SPCADD ØR MPCADD UNIØN CØNSISTS ØF A SINGLE SET.

4125 *** USER FATAL MESSAGE 4125, MAXIMUM ALLØWABLE HARMØNIC ID IS 99. DATA CØNTAINS MAXIMUM = ****.

4126 *** USER FATAL MESSAGE 4126, BAD DATA ØR FØRMAT ØR NØNUNIQUE NAME, DMIAX ****.

4127 *** USER FATAL MESSAGE 4127, USER TAPE **** NØT SET UP.

4128 *** USER FATAL MESSAGE 4128, MØDULE ØUTPUT1 - END-ØF-FILE ENCØUNTERED WHILE ATTEMPTING TØ READ TAPE ID CØDE ØN USER TAPE ****.

4129 *** USER FATAL MESSAGE 4129, MØDULE ØUTPUT1 - END-ØF-RECØRD ENCØUNTERED WHILE ATTEMPTING TØ READ TYPE ID CØDE ØN USER TAPE ****.

4130 *** USER FATAL MESSAGE 4130, MØDULE $\begin{Bmatrix}\text{ØUTPUT1}\\ \text{ØUTPUT2}\end{Bmatrix}$ - ILLEGAL TAPE CØDE HEADER = *******************.

4131 *** USER WARNING MESSAGE 4131, $\begin{Bmatrix}\text{USER}\\ \text{FØRTRAN}\end{Bmatrix}$ TAPE ID CØDE - ******** - DØES NØT MATCH THIRD $\begin{Bmatrix}\text{ØUTPUT1}\\ \text{ØUTPUT2}\end{Bmatrix}$ DMAP PARAMETER - ********.

4132 *** USER FATAL MESSAGE 4132, MØDULE INPUTT1 - END-ØF-FILE ENCØUNTERED WHILE ATTEMPTING TØ READ TAPE ID CØDE ØN USER TAPE ****.

4133 *** USER FATAL MESSAGE 4133, MØDULE INPUTT1 - END-ØF-RECØRD ENCØUNTERED WHILE ATTEMPTING TØ READ TAPE ID CØDE ØN USER TAPE ****.

4134 *** USER FATAL MESSAGE 4134, MØDULE $\begin{Bmatrix}\text{INPUTT1}\\ \text{INPUTT2}\end{Bmatrix}$ - ILLEGAL TAPE CØDE HEADER = ******************.

4135 *** USER WARNING MESSAGE 4135, USER TAPE ID CØDE - ******** DØES NØT MATCH THIRD $\begin{Bmatrix}\text{INPUTT1}\\ \text{INPUTT2}\end{Bmatrix}$ DMAP PARAMETER - ******** -.

4136 *** USER FATAL MESSAGE 4136, USER TAPE ID CØDE - ******** - DØES NØT MATCH THIRD $\begin{Bmatrix}\text{INPUTT1}\\ \text{INPUTT2}\end{Bmatrix}$ DMAP PARAMETER - ******** -.

4137 *** USER WARNING MESSAGE 4137, ALL ØUTPUT DATA BLØCKS FØR $\begin{Bmatrix}\text{INPUTT1}\\ \text{INPUTT2}\end{Bmatrix}$ ARE PURGED.

4138 *** USER WARNING MESSAGE 4138, DATA BLØCK ******** (DATA BLØCK CØUNT = ****) HAS PREVIØUSLY BEEN RETRIEVED FRØM $\begin{Bmatrix}\text{USER}\\ \text{FØRTRAN}\end{Bmatrix}$ TAPE **** AND WILL BE IGNØRED.

4139 *** USER INFØRMATIØN MESSAGE 4139, DATA BLØCK ******** RETRIEVED FRØM $\begin{Bmatrix}\text{USER}\\ \text{FØRTRAN}\end{Bmatrix}$ TAPE **** (DATA BLØCK CØUNT = *****).

4140 *** USER WARNING MESSAGE 4140, SECØNDARY VERSIØN ØF DATA BLØCK HAS REPLACED EARLIER ØNE.

4141 *** USER WARNING MESSAGE 4141, ØNE ØR MØRE DATA BLØCKS NØT FØUND ØN $\begin{Bmatrix}\text{USER}\\ \text{FØRTRAN}\end{Bmatrix}$ TAPE.

4142 *** USER FATAL MESSAGE 4142, ØNE ØR MØRE DATA BLØCKS NØT FØUND ØN USER TAPE.

4143 *** USER INFØRMATIØN MESSAGE 4143, THIS IS AN UNMØDIFIED RESTART.

4144 *** USER INFØRMATIØN MESSAGE 4144, THIS IS A MØDIFIED RESTART.

4145 *** USER INFØRMATIØN MESSAGE 4145, THIS IS A MØDIFIED RESTART INVØLVING RIGID FØRMAT SWITCH.

4146 *** SYSTEM FATAL MESSAGE 4146, LØGIC ERRØR IN SUBRØUTINE XGPI WHILE PRØCESSING DATA CHANGES FØR MØDIFIED RESTART.

4147 *** USER INFØRMATIØN MESSAGE 4147, NØTE THAT ADDITIØNAL DMAP INSTRUCTIØNS (NØT INDICATED BY

AN * IN THE DMAP SØURCE LISTING) NEED TØ BE FLAGGED FØR EXECUTIØN IN ØRDER TØ GENERATE CERTAIN REQUIRED DATA BLØCKS. SUCH INSTRUCTIØNS AND THE ASSØCIATED DATA BLØCKS ARE IDENTIFIED BELØW.

4148 *** USER INFØRMATIØN MESSAGE 4148, NØTE THAT ADDITIØNAL DMAP INSTRUCTIØNS (NØT INDICATED BY AN * IN THE DMAP SØURCE LISTING) NEED TØ BE FLAGGED FØR EXECUTIØN SINCE THIS UNMØDIFIED RESTART INVØLVES DMAP LØØPING AND THE REENTRY PØINT IS WITHIN A DMAP LØØP. SUCH INSTRUCTIØNS ARE IDENTIFIED BELØW. THE EXECUTIØN WILL, HØWEVER, RESUME AT THE LAST REENTRY PØINT (DMAP INSTRUCTIØN NØ. ****).

4149 *** USER FATAL MESSAGE 4149, ATTEMPT TØ ADD MATRICES ØF UNEQUAL ØRDER IN MØDULE $\left\{\begin{matrix}\text{ADD}\\\text{ADD5}\end{matrix}\right\}$.

5000 *** USER FATAL MESSAGE 5000, NEG. ØR ZERØ RADIUS DETECTED FØR CFLUID2 ELEMENT. ELEMENT NØ. ****.

6.7 FUNCTIONAL MODULE MESSAGES (5001 THRU 6000)

5001 *** USER FATAL MESSAGE 5001, NEG. ØR ZERØ RADIUS DETECTED FØR CFLUID3 ØR CFLUID4 ELEMENT. ELEMENT NØ. ****.

5002 *** USER FATAL MESSAGE 5002, INTERIØR ANGLE GREATER THAN ØR EQUAL TØ 180 DEGREES. CFLUID4 ELEMENT NØ. ****.

5003 *** USER FATAL MESSAGE 5003, ZERØ XZ VALUE ØN RINGFL CARD WITH SPHERICAL CØØRDINATES. FLUID PØINT ID = ****.

5004 *** USER FATAL MESSAGE 5004, FLUID PØINT ID ØN CFLUIDI ØR RINGFL CARD GT 99999.

5011 *** USER FATAL MESSAGE 5011, FIRST PARAMETER ***** NE TRAILER RECØRD PARAMETER *****.

5012 *** USER FATAL MESSAGE 5012, ENTRY ***** ØF SIL TABLE INCØMPATIBLE WITH NEXT ENTRY.

6.8 FUNCTIONAL MODULE MESSAGES (6001 THRU 7000)

6001 *** USER FATAL MESSAGE 6001, SUBSTRUCTURE DATA IS REQUIRED WITH THIS APPRØACH.

The program expects a SUBSTRUCTURE card following the CEND card if APP DISP, SUBS was used.

6002 *** USER WARNING MESSAGE 6002, INCØRRECT PHASE DATA.

The second word on the substructure command should be PHASEi, i = 1, 2, 3. The default is 2.

6003 *** USER FATAL MESSAGE 6003, ILLEGAL CØMMAND ØR ØPTIØN DEFINED ØN PREVIØUS CARD.

The program does not recognize the previous card. If any "subcommand" cards follow this error, they may produce this message until a legitimate command card is encountered.

6004 *** USER WARNING MESSAGE 6004, NØ PREFIX DEFINED AFTER EQUIVALENCE CØMMAND.

A prefix must be defined to identify the equivalent lower level basic substructures. To equivalence a basic substructure also requires that the prefix be defined.

6005 *** USER FATAL MESSAGE 6005, ILLEGAL ØR MISSING INPUT DATA GIVEN FØR PREVIØUS CØMMAND.

Either the basic command data is insufficient or mandatory additional subcommands are missing.

6006 *** USER FATAL MESSAGE 6006, DMAP ALTERS INTERFERE WITH SUBSTRUCTURE ALTERS.

The DMAP instruction numbers on the user ALTER data cards overlap or conflict with the sections automatically modified. Use DIAG 23 to print the DMAP ALTER package or see Sections 5 and 3. Note also that the card APP DISPLACEMENT,SUBS,1 suppresses the automatic generation of DMAP instructions.

6007 *** SYSTEM FATAL MESSAGE 6007, IMPRØPER FILE SETUP FØR ****.

An external I/Ø operation has been defined but the file is missing or the card is improper. Occurs due to previously listed errors or from an illegal format in the NPTP or CASECC file.

6008 *** USER FATAL MESSAGE 6008, ILLEGAL INPUT ØN THE PREVIØUS CØMMAND. MISSING FILE NAME FØR I/Ø ØPERATIØN.

The EXIØ commands, SØFIN, SØFØUT, DUMP, etc. require a file name.

6009 *** SYSTEM FATAL MESSAGE 6009, UNRECØVERABLE ERRØR CØNDITIØNS IN SUBRØUTINE ASDMAP.

An unusual combination of previously listed errors or program errors will cause this condition.

6010 *** SYSTEM FATAL MESSAGE 6010, ILLEGAL VARIABLE TØ BE SET IN DMAP STATEMENT, (N).

The system has encountered an illegal type of word to be inserted in a DMAP sequence. For example, a floating point number is used instead of an integer on an input card.

6011 *** USER FATAL MESSAGE 6011, MISSING PASSWØRD ØR SØF DATA.

The SØF and PASSWØRD cards are mandatory. At least one SØF file, SØF(1), must be defined.

6012 *** SYSTEM FATAL MESSAGE 6012, FILE=**** IS PURGED ØR NULL AND IS REQUIRED IN PHASE1 SUBSTRUCTURE ANALYSIS.

The error will occur due to user DMAP ALTERs or if no grid or scalar points are defined.

6013 *** USER FATAL MESSAGE 6013, ILLEGAL TYPE ØF PØINT DEFINED FØR SUBSTRUCTURE ANALYSIS. PØINT NUMBER=********.

An illegal type of grid point (i.e., aero or axisymmetric) has been encountered.

6014 *** USER FATAL MESSAGE 6014, INSUFFICIENT CØRE TØ LØAD TABLES IN MØDULE SUBPH1, CØRE= ********.

At least three words of core per grid point are required.

6015 *** USER FATAL MESSAGE 6015, TØØ MANY CHARACTERS TØ BE INSERTED IN A DMAP LINE. N=****.

A BCD word has been defined with too many characters to fit the space in the DMAP. (Usual limit = 8). Message could also occur if any of the subroutines ASCMxx has an error.

6016 *** USER FATAL MESSAGE 6016, TØØ MANY DIGITS TØ BE INSERTED IN DMAP VALUE=***.

An integer is limited to eight digits.

6017 *** USER FATAL MESSAGE 6017, MISSING ENDSUBS CARD.

6022 *** USER FATAL MESSAGE 6022, SUBSTRUCTURE ***, GRID PØINT ***, CØMPØNENT ***, REFERENCED ØN *** CARD DØES NØT EXIST IN SØLUTIØN STRUCTURE ***.

6023 *** USER WARNING MESSAGE 6023, REQUESTED PLØT SET NØ. ****************** HAS NØT BEEN DEFINED.

The requested set must be defined in the plot control deck in Case Control.

6101 *** SYSTEM FATAL MESSAGE 6101, REQUESTED SØF ITEM DØES NØT EXIST. ITEM ***, SUBSTRUCTURE ***.

Either the item has never been created or it only pseudo exists in a prior dry run.

6102 *** SYSTEM FATAL MESSAGE 6102, REQUESTED SUBSTRUCTURE DØES NØT EXIST. ITEM ***, SUBSTRUCTURE ***.

The user has probably misspelled the substructure name or is using the wrong SØF.

6103 *** SYSTEM FATAL MESSAGE 6103, REQUESTED SØF ITEM HAS INVALID NAME. ITEM ***, SUBSTRUCTURE ***.

Item name is illegal. Occurs with user DMAP ALTERs only.

6104 *** SYSTEM FATAL MESSAGE 6104, ATTEMPT TØ CREATE DUPLICATE SUBSTRUCTURE NAME ***.

6105 *** USER FATAL MESSAGE 6105, ATTEMPT TØ RE-USE SUBSTRUCTURE *** IN A REDUCE ØR CØMBINE ØPERATIØN. USE EQUIV SUBSTRUCTURE CØMMAND.

A single substructure may be reduced or combined more than once only after it is given a new name with the EQUIV substructure command.

6106 *** SYSTEM FATAL MESSAGE 6106, UNEXPECTED END ØF GRØUP ENCØUNTERED WHILE READING ITEM *** SUBSTRUCTURE ***.

Required data is missing or is of inconsistent length.

6107 *** SYSTEM FATAL MESSAGE 6107, UNEXPECTED END ØF ITEM ENCØUNTERED WHILE READING ITEM *** SUBSTRUCTURE ***.

One or more of the required number of data groups is missing.

6108 *** SYSTEM FATAL MESSAGE 6108, INSUFFICIENT SPACE ØN SØF FØR ITEM ***, SUBSTRUCTURE ***.

6201 *** SYSTEM INFØRMATIØN MESSAGE 6201, *** FILES HAVE BEEN ALLØCATED TØ THE SØF WHERE
SIZE OF FILE 1 = *** BLØCKS
.
.
.
SIZE ØF FILE *** = *** BLØCKS
AND WHERE A BLØCK CØNTAINS *** WØRDS

6202 *** USER FATAL MESSAGE 6202, THE REQUESTED NUMBER ØF FILES IS NØN-PØSITIVE.

SØF file declaration is missing or illegal.

6204 *** SYSTEM FATAL MESSAGE 6204, SUBRØUTINE *** - THE SUBRØUTINE SØFØPN SHØULD BE CALLED PRIØR TØ ANY ØF THE SØF UTILITY SUBRØUTINES.

6205 *** USER FATAL MESSAGE 6205, SUBRØUTINE *** - THE BUFFER SIZE HAS BEEN MØDIFIED.

The BUFFSIZE entry on the NASTRAN card input has been changed.

6206 *** USER FATAL MESSAGE 6206, SUBRØUTINE *** - WRØNG PASSWØRD ØN SØF FILE ***.

6207 *** USER FATAL MESSAGE 6207, SUBRØUTINE *** - THE SØF FILE *** IS ØUT ØF SEQUENCE.

The SØF file declarations are in the wrong order.

6208 *** USER FATAL MESSAGE 6208, SUBRØUTINE *** - THE SIZE ØF THE SØF FILE *** HAS BEEN MØDIFIED.

Only the last SØF file may be increased. None may be decreased.

6209 *** USER FATAL MESSAGE 6209, SUBRØUTINE *** - THE NEW SIZE ØF FILE *** IS TØØ SMALL.

6211 *** USER WARNING MESSAGE 6211, MØDULE *** - ITEM *** ØF SUBSTRUCTURE *** HAS ALREADY BEEN WRITTEN.

Program will not write over existing data.

6212 *** USER WARNING MESSAGE 6212, MØDULE *** - THE SUBSTRUCTURE *** DØES NØT EXIST.

6213 *** USER WARNING MESSAGE 6213, MØDULE *** - *** IS AN ILLEGAL ITEM NAME.

6215 *** USER WARNING MESSAGE 6215, MØDULE *** - ITEM *** ØF SUBSTRUCTURE *** PSEUDØ-EXISTS ØNLY.

6216 *** USER WARNING MESSAGE 6216, MØDULE *** - ITEM *** ØF SUBSTRUCTURE *** DØES NØT EXIST.

6217 *** USER WARNING MESSAGE 6217, MØDULE *** - *** IS AN ILLEGAL PARAMETER NAME.

6218 *** USER WARNING MESSAGE 6218, MØDULE *** - THE SUBSTRUCTURE *** CANNØT BE DESTRØYED BECAUSE IT IS AN IMAGE SUBSTRUCTURE.

6219 *** USER WARNING MESSAGE 6219, MØDULE *** RUN EQUALS DRY ØR STEP, AND, SUBSTRUCTURE *** ØR ØNE ØF THE NEW NAMES ALREADY EXISTS.

6220 *** USER WARNING MESSAGE 6220, MØDULE *** - RUN EQUALS GØ, AND, SUBSTRUCTURE *** ØR ØNE ØF THE NEW NAMES DØES NØT EXIST.

6222 *** SYSTEM FATAL MESSAGE 6222 - ATTEMPT TØ CALL SØFØPN MØRE THAN ØNCE WITHØUT CALLING SØFCLS.

6223 *** USER FATAL MESSAGE 6223, SUBRØUTINE *** - THERE ARE NØ MØRE FREE BLØCKS AVAILABLE ØN THE SØF.

6224 *** SYSTEM FATAL MESSAGE 6224, SØF UTILITY SUBRØUTINE ***.

Text follows the message to describe the error.

6225 *** SYSTEM FATAL MESSAGE 6225, BLØCK NUMBER *** ØUT ØF RANGE ØF SØF FILES.

This means the SØF file does not contain all the data expected. Check previous jobs to verify where the intended SØF write operation may have failed, or determine if more information was expected.

6226 *** SYSTEM WARNING MESSAGE 6226, SUBRØUTINE SØFIØ - HIBLK PARAMETER FØR SØFIØ DID NØT CØNFØRM TØ PHYSICAL FILE. PARAMETER VALUE HAS BEEN CHANGED FRØM *** TØ ***.

This can be caused when the previous run using the SØF terminated abnormally. (CDC only.)

6227 *** SYSTEM FATAL MESSAGE 6227, AN ATTEMPT HAS BEEN MADE TØ ØPERATE ØN THE MATRIX ITEM *** ØF SUBSTRUCTURE *** USING SFETCH.

6228 *** USER INFØRMATIØN MESSAGE 6228, SUBSTRUCTURE *** IS ALREADY EQUIVALENT TØ SUBSTRUCTURE ***. ØNLY ITEMS NØT PREVIØUSLY EXISTING FØR *** HAVE BEEN MADE EQUIVALENT.

6229 *** USER INFØRMATIØN MESSAGE 6229, SUBSTRUCTURE *** HAS BEEN RENAMED TØ ***.

6230 *** USER WARNING MESSAGE 6230, SUBSTRUCTURE *** HAS NØT BEEN RENAMED BECAUSE *** ALREADY EXISTS ØN THE SØF.

6231 *** USER WARNING MESSAGE 6231, INSUFFICIENT CØRE AVAILABLE ØR ILLEGAL ITEM FØRMAT REQUIRES AN UNFØRMATTED DUMP TØ BE PERFØRMED FØR ITEM *** ØF SUBSTRUCTURE ***.

6232 *** SYSTEM FATAL MESSAGE 6232, ERRØR ØCCURRED WHILE INITIALIZING SØF FILE ***.

An error occurred while initializing an SØF file on the IBM 360/370. The nature of the error follows the message.

6233 *** USER WARNING MESSAGE 6233, THE ITEM STRUCTURE HAS BEEN CHANGED ØN THE SØF. NEW CAPABILITIES USING THESE ITEMS MAY NØT BE USED WITH THIS SØF.

6234 *** USER FATAL MESSAGE 6234, THE NASTRAN BUFFER SIZE IS TØØ SMALL FØR THE SØF FILE. MINIMUM BUFFER SIZE IS ***.

6235 *** USER WARNING MESSAGE 6235, THE ØLD SØF CØNTAINS NØ ITEM STRUCTURE INFØRMATIØN. THE LEVEL 16.0 ITEM STRUCTURE WILL BE USED.

6236 *** USER WARNING MESSAGE 6236, DURING THE CREATIØN ØF A NEW IMAGE SUBSTRUCTURE NAME, THE LAST CHARACTER ØF SUBSTRUCTURE NAME *** WAS TRUNCATED TØ MAKE RØØM FØR THE PREFIX.

6237 *** SYSTEM WARNING MESSAGE 6237, THE SØFTØC RØUTINE CAN HANDLE ØNLY *** ITEMS. ADDITIØNAL ITEMS WILL NØT BE SHØWN.

6301 *** SYSTEM FATAL MESSAGE 6301, DATA MISSING IN GØ MØDE FØR SUBSTRUCTURE ***, ITEM ***.

Item created in dry run mode has been deleted by the user or lost due to errors.

6302 *** SYSTEM FATAL MESSAGE 6302, *** IS ILLEGAL MATRIX TYPE FØR MØDULE CØMB2.

6303 *** SYSTEM FATAL MESSAGE 6303, HØRG TRANSFØRMATIØN MATRIX FØR SUBSTRUCTURE *** CANNØT BE FØUND ØN SØF.

6304 *** SYSTEM FATAL MESSAGE 6304, MØDULE CØMB2 INPUT MATRIX NUMBER *** FØR SUBSTRUCTURE *** HAS INCØMPATIBLE DIMENSIØNS.

Matrix dimensions conflict with those of its H or G transformation matrix.

6305 *** SYSTEM WARNING MESSAGE 6305, RECØRD NUMBER *** ØF CASESS IS NØT A RECØVER RECØRD. IT IS A *** RECØRD.

The step parameter for module RCØVR in incorrect. It should be the CASESS record number of a recover record.

6306 *** USER WARNING MESSAGE 6306, ATTEMPT TØ RECØVER DISPLACEMENTS FØR NØN-EXISTENT SUBSTRUCTURE ***.

6307 *** USER WARNING MESSAGE 6307, WHILE ATTEMPTING TØ RECØVER DISPLACEMENTS FØR SUBSTRUCTURE ***, THE DISPLACEMENTS FØR SUBSTRUCTURE *** WERE FØUND TØ EXIST IN DRY RUN FØRM ØNLY.

Before you can recover displacements of any substructure, you must first perform an actual solution. See RUN substructure command.

6308 *** USER WARNING MESSAGE 6308, NØ SØLUTIØN AVAILABLE FRØM WHICH DISPLACEMENTS FØR SUBSTRUCTURE *** CAN BE RECØVERED. HIGHEST LEVEL SUBSTRUCTURE FØUND WAS ***.

Solve the highest level substructure found or combine it to an even higher level and solve.

6309 *** SYSTEM FATAL MESSAGE 6309, INSUFFICIENT TIME REMAINING TØ RECØVER DISPLACEMENTS ØF SUBSTRUCTURE *** FRØM THØSE ØF SUBSTRUCTURE ***. (PRØCESSING USER RECØVER REQUEST FØR SUBSTRUCTURE ***.)

6310 *** SYSTEM WARNING MESSAGE 6310, INSUFFICIENT SPACE ØN SØF TØ RECØVER DISPLACEMENTS ØF SUBSTRUCTURE *** FRØM THØSE ØF SUBSTRUCTURE *** WHILE PRØCESSING USER RECØVER REQUEST FØR SUBSTRUCTURE ***.

Use the SØF substructure command and increase the size of the SØF and/or add more SØF units. Alternatively, use EDIT to remove unwanted data.

6311 *** SYSTEM WARNING MESSAGE 6311, SDCØMP DECØMPØSITIØN FAILED ØN KØØ MATRIX FØR SUBSTRUCTURE ***.

The KØØ matrix has been changed from the original REDUCE run. The local effects of non-boundary loads will be ignored.

6312 *** USER INFØRMATIØN MESSAGE 6312, LEVEL *** DISPLACEMENTS FØR SUBSTRUCTURE *** HAVE BEEN RECØVERED AND SAVED ØN SØF.

6313 *** SYSTEM WARNING MESSAGE 6313, INSUFFICIENT CØRE FØR RCØVR MØDULE WHILE TRYING TØ PRØCESS PRINTØUT DATA BLØCKS FØR SUBSTRUCTURE.

6314 *** SYSTEM WARNING MESSAGE 6314, ØUTPUT REQUEST CANNØT BE HØNØRED. RCØVR MØDULE ØUTPUT DATA BLØCK *** IS PURGED.

An illegal type of output for the solution rigid format has been requested.

6315 *** USER WARNING MESSAGE 6315, RCØVR MØDULE IS UNABLE TØ FIND SUBSTRUCTURE *** AMØNG THØSE ØN EQSS. LØAD SET *** FØR THAT SUBSTRUCTURE WILL BE IGNØRED IN CREATING THE SØLN ITEM FØR FINAL SØLUTIØN STRUCTURE ***.

Illegal name used in PRINT or SAVE request.

6316 *** USER WARNING MESSAGE 6316, RCØVR MØDULE IS UNABLE TØ FIND LØAD SET *** FØR SUBSTRUCTURE *** AMØNG THØSE ØN LØDS. IT WILL BE IGNØRED IN CREATING THE SØLN ITEMS FØR FINAL SØLUTIØN STRUCTURE ***.

Case Control data was probably changed between SØLVE and the first RECØVER steps. Message 6331 will define the error in SØLVE.

6317 *** SYSTEM WARNING MESSAGE 6317, RECØVER ØF DISPLACEMENTS FØR SUBSTRUCTURE *** ABØRTED.

6318 *** SYSTEM WARNING MESSAGE 6318, ØUTPUT REQUEST FØR REACTIØN FØRCES IGNØRED.

6319 *** SYSTEM WARNING MESSAGE 6319, DISPLACEMENT MATRIX FØR SUBSTRUCTURE *** MISSING. DISPLACEMENT ØUTPUT REQUESTS CANNØT BE HØNØRED AND SPCFØRCE ØUTPUT REQUESTS CANNØT BE HØNØRED UNLESS THE REACTIØNS HAVE BEEN PREVIØUSLY CØMPUTED.

6320 *** SYSTEM WARNING MESSAGE 6320, LØADC DATA MISSING FØR SUBSTRUCTURE ***, EXTERNAL STATIC LØAD SET ***.

No LØADC bulk data cards can be found on GEØM4 or GEØM4 is purged.

6321 *** USER INFØRMATIØN MESSAGE 6321, SUBSTRUCTURE PHASE3 RECØVER FØR FINAL SØLUTIØN STRUCTURE *** AND BASIC SUBSTRUCTURE ***.

6322 *** SYSTEM FATAL MESSAGE 6322, SØLN ITEM HAS INCØRRECT RIGID FØRMAT NUMBER. PHASE2 RIGID FØRMAT WAS *** AND PHASE3 IS ***.

The Rigid Format of Phase 3 must be the same as that used in Phase 2 to obtain the solution.

6323 *** USER WARNING MESSAGE 6323, NØ EIGENVALUES FØR THIS SØLUTIØN.

6324 *** USER FATAL MESSAGE 6324, PHASE3 RECØVER ATTEMPTED FØR NØN-BASIC SUBSTRUCTURE ***.

Substructure Phase 3 can be executed only for basic substructures or their equivalents.

6325 *** USER WARNING MESSAGE 6325, SUBSTRUCTURE PHASE1, BASIC SUBSTRUCTURE *** ALREADY EXISTS ØN SØF. ITEMS WHICH ALREADY EXIST WILL NØT BE REGENERATED.

Use DESTRØY or EDIT to remove items which are to be regenerated.

6326 *** USER WARNING MESSAGE 6326, SUBSTRUCTURE ***, ITEM *** ALREADY EXISTS ØN SØF.

Follows message 6325, above.

6327 *** USER INFØRMATIØN MESSAGES 6327, SUBSTRUCTURE ***, SUBCASE *** IS IDENTIFIED BY *** SET *** IN LØDS ITEM. REFER TØ THIS NUMBER ØN LØADC CARDS.

6328 *** SYSTEM FATAL MESSAGE 6328, MØRE THAN 100 SUBCASES DEFINED. SGEN PRØGRAM LIMIT EXCEEDED.

To increase this limit to more than 100 subcases, change the dimensions of local arrays LØAD, MPC and SPC in subroutine SGEN and change the IF test which causes termination.

6329 *** USER FATAL MESSAGE 6329, SUBSTRUCTURE ***, REFERENCES ØN *** CARD, IS NØT A CØMPØNENT BASIC SUBSTRUCTURE ØF SØLUTIØN STRUCTURE ***.

6330 *** USER FATAL MESSAGE 6330, SØLUTIØN SUBSTRUCTURE *** -- *** AND CARDS CANNØT BE USED TØGETHER. USE EITHER ØNE, BUT NØT BØTH.

6331 *** USER FATAL MESSAGE 6331, SØLUTIØN SUBSTRUCTURE *** -- LØADC SET *** REFERENCES UNDEFINED LØAD SET *** ØF BASIC SUBSTRUCTURE ***.

6332 *** SYSTEM FATAL MESSAGE 6332, CANNØT FIND LØAD VECTØR NUMBER *** IN LØAD MATRIX ØF *** CØLUMNS BY *** RØWS FØR SØLUTIØN STRUCTURE ***.

The wrong load matrix is being used.

6333 *** USER FATAL MESSAGE 6333, *** IS AN INVALID FØRMAT PARAMETER FØR MØDULE EXIØ.

An illegal value was given in the SØFIN, SØFØUT, DUMP or RESTØRE command.

6334 *** USER WARNING MESSAGE 6334, EXIØ DEVICE PARAMETER SPECIFIES TAPE, BUT UNIT *** IS NØT A PHYSICAL TAPE.

6335 *** USER WARNING MESSAGE 6335, *** IS AN INVALID DEVICE FØR MØDULE EXIØ.

6336 *** USER INFØRMATIØN MESSAGE 6336, EXIØ FILE IDENTIFICATIØN. PASSWØRD ***. DATE ***. TIME ** ** **.

This message is caused when an I/Ø operation is requested. The date (in the form mm/dd/yy) and the time (in the form hh=mm=ss) indicate when the operation began.

6337 *** USER INFØRMATIØN MESSAGE 6337, *** BLØCKS (*** SUPERBLØCKS) ØF THE SØF SUCCESSFULLY DUMPED TØ EXTERNAL FILE ***.

6338 *** USER WARNING MESSAGE 6338, *** IS AN INVALID MØDE PARAMETER FØR MØDULE EXIØ.

6339 *** USER WARNING MESSAGE 6339, *** IS AN INVALID FILE PØSITIØNING PARAMETER FØR MØDULE EXIØ.

6340 *** USER WARNING MESSAGE 6340, SUBSTRUCTURE *** ITEM *** PSEUDØ-EXISTS ØNLY AND CANNØT BE CØPIED ØUT BY EXIØ.

6341 *** USER INFØRMATIØN MESSAGE 6341, SUBSTRUCTURE *** ITEM *** SUCCESSVULLY CØPIED FRØM *** TØ *** (***, ***).

The message follows message 6336 to indicate the substructure item that was copied, the input file, and the output file. The information in parenthesis is the date and time in the same form as described under message 6336.

6342 *** USER WARNING MESSAGE 6342, SØF RESTØRE ØPERATIØN FAILED. THE RESIDENT SØF IS NØT EMPTY.

Use the NEW option on the SØF substructure command to create a "new" SØF.

6343 *** SYSTEM WARNING MESSAGE 6343, *** IS NØT AN EXTERNAL SØF FILE.

Either (1) tape contained no data, (2) first record read was not an ID or header record, (3) tape was incorrectly positioned, or (4) GINØ buffer size was changed.

6344 *** USER INFØRMATIØN MESSAGE 6344, SØF RESTØRE ØF *** BLØCKS SUCCESSFULLY CØMPLETED.

6345 *** USER WARNING MESSAGE 6345, SUBSTRUCTURE *** ITEM *** IS DUPLICATED ØN EXTERNAL FILE ***. ØLDER VERSIØN (***, ***) IS IGNØRED.

6346 *** USER WARNING MESSAGE 6346, SUBSTRUCTURE *** ITEM *** NØT CØPIED. IT ALREADY EXISTS ØN THE SØF.

6347 *** USER INFØRMATIØN MESSAGE 6347, SUBSTRUCTURE *** ADDED TØ THE SØF.

HIGHER LEVEL SUBSTRUCTURE ********

CØMBINED SUBSTRUCTURE ********

LØWER LEVEL SUBSTRUCTURE ********

6348 *** USER WARNING MESSAGE 6348, SUBSTRUCTURE *** ITEM *** NØT FØUND ØN EXTERNAL FILE ***.

6349 *** USER INFØRMATIØN MESSAGE 6349, CØNTENTS ØF EXTERNAL SØF FILE *** FØLLØW.

6350 *** USER WARNING MESSAGE 6350, SØF APPEND ØF FILE *** FAILED. "text"

"text" explains why the append operation failed.

6351 *** USER WARNING MESSAGE 6351, DUPLICATE SUBSTRUCTURE NAME *** FØUND DURING SØF APPEND ØF FILE ***. THE SUBSTRUCTURE WITH THIS NAME ØN THE FILE BEING APPENDED WILL BE PREFIXED WITH "Q".

6352 *** USER INFØRMATIØN MESSAGE 6352, EXTERNAL SØF FILE *** SUCCESSFULLY APPENDED TØ THE

RESIDENT SØF.

6353 *** USER INFØRMATIØN MESSAGE 6353, SUBSTRUCTURE *** ITEM *** HAS BEEN SUCCESSFULLY CØMPRESSED.

6354 *** USER INFØRMATIØN MESSAGE 6354, THERE ARE *** FREE BLØCKS (*** WØRDS) ØN THE RESIDENT SØF.

6355 *** SYSTEM INFØRMATIØN MESSAGE 6355, EXIØ TERMINATED WITH ERRØRS. DRY RUN MØDE ENTERED.

The parameter DRY has been set to -2 to prevent matrix operations from occurring down stream in this run.

6356 *** USER WARNING MESSAGE 6356, *** IS AN INVALID UNIT FØR MØDULE EXIØ, EXTERNAL FØRMAT.

6357 *** USER INFØRMATIØN MESSAGE 6357, SUBSTRUCTURE *** ITEM *** SUCCESSFULLY CØPIED FRØM *** TØ ***.

6358 *** SYSTEM WARNING MESSAGE 6358, ILLEGAL RIGID FØRMAT NUMBER *** IN SØLN ITEM FØR SUBSTRUCTURE ***. THE ITEM WILL NØT BE CØPIED.

6359 *** USER INFØRMATIØN MESSAGE 6359, SUBSTRUCTURE *** WAS ØRIGINALLY A SECØNDARY SUBSTRUCTURE. ØN THIS SØF, IT IS A PRIMARY SUBSTRUCTURE.

6360 *** SYSTEM WARNING MESSAGE 6360, SØFØUT (EXTERNAL) ENCØUNTERED AN UNSUPPØRTED TABLE ITEM ***. THE ITEM WILL NØT BE CØPIED.

6361 *** USER INFØRMATIØN MESSAGE 6361, PHASE1 SUCCESSFULLY EXECUTED FØR SUBSTRUCTURE ***.

6362 *** USER FATAL MESSAGE 6362, MPCS SET *** IS ILLEGAL. SUBSTRUCTURE *** GRID PØINT *** CØMPØNENT *** SIGNIFIES A NØN-UNIQUE DEPENDENT DEGREE ØF FREEDØM.

6363 *** USER WARNING MESSAGE 6363, INCØMPLETE DATA FØR SUBSTRUCTURE *** ITEM *** ØN ***. THE ALL ØUTPUT WILL BE PRØDUCED.

6365 *** USER WARNING MESSAGE 6365, REQUESTED ØUTPUT SET ID *** IS NØT DECLARED IN CASE CØNTRØL, ALL ØUTPUT WILL BE PRØDUCED.

Add 'SET N = list' to the Case Control Deck.

6366 *** USER WARNING MESSAGE 6366, THE RECØVER ØUTPUT CØMMAND SØRT MUST APPEAR BEFØRE THE FIRST BASIC SUBCØMMAND. ANY ØTHER SØRT CØMMANDS ARE IGNØRED.

6367 *** USER WARNING MESSAGE 6367, ILLEGAL FØRMAT ØN THE RECØVER ØUTPUT CØMMAND ***, CØMMAND IGNØRED.

6368 *** USER WARNING MESSAGE 6368, THE SUBSTRUCTURE *** APPEARING ØN A BASIC CØMMAND IS NØT A CØMPØNENT ØF ***. ALL ØUTPUT REQUESTS UNTIL THE NEXT BASIC, PRINT, ØR SAVE ARE IGNØRED.

6369 *** USER FATAL MESSAGE 6369, SØLN ITEM HAS INCØRRECT RIGID FØRMAT NUMBER. SØLUTIØN RIGID FØRMAT WAS *** AND CURRENT NASTRAN EXECUTIØN RIGID FØRMAT IS ***.

6370 *** USER FATAL MESSAGE 6370, A SØLUTIØN ØN SUBSTRUCTURE *** WAS ATTEMPTED BUT PREVIØUS SØLUTIØN DATA EXISTED IN ITEM ***. THIS DATA MUST BE DELETED BEFØRE A NEW SØLUTIØN CAN BE PERFØRMED.

6371 *** USER WARNING MESSAGE 6371, MØDAL REDUCTIØN ENERGY CALCULATIØNS FØR SUBSTRUCTURE *** ABØRTED.

6501 *** USER FATAL MESSAGE 6501, THE MANUAL CØMBINE ØPTIØN HAS BEEN SPECIFIED, BUT NØ CØNNECTIØN SET WAS GIVEN.

6505 *** USER FATAL MESSAGE 6505, THE SYMMETRY ØPTIØN *** CØNTAINS AN INVALID SYMBØL.

See the CØMBINE substructure control description.

6506 *** USER FATAL MESSAGE 6506, THE CØMPØNENT SUBSTRUCTURE *** IS NØT ØNE ØF THØSE ØN THE CØMBINE CARD.

6507 *** USER FATAL MESSAGE 6507, THE SUBSTRUCTURE *** DØES NØT EXIST ØN THE SØF.

6508 *** USER FATAL MESSAGE 6508, THE NAME SPECIFIED FØR THE RESULTANT PSEUDØSTRUCTURE ALREADY EXISTS ØN THE SØF.

6510 *** USER FATAL MESSAGE 6510, THE REQUESTED CØMBINE ØPERATIØN REQUIRES SUBSTRUCTURE BULK DATA WHICH HAS NØT BEEN GIVEN.

A CØNNECT request requires CØNCT, CØNCT1 or RELES data.

6511 *** USER FATAL MESSAGE 6511, THE REQUESTED TRANS SET ID *** HAS NØT BEEN DEFINED BY BULK DATA.

6512 *** USER FATAL MESSAGE 6512, REDUNDANT CØNNECTIØN SET ID-S HAVE BEEN SPECIFIED.

6513 *** USER FATAL MESSAGE 6513, THE TRANS SET ID *** REQUESTED BY A GTRAN BULK DATA CARD HAS NØT BEEN DEFINED.

6514 *** USER FATAL MESSAGE 6514, ERRØRS HAVE BEEN FØUND IN THE MANUALLY SPECIFIED CØNNECTIØN ENTRIES. SUMMARY FØLLØWS.

6515 *** USER FATAL MESSAGE 6515, GRID PØINT *** BASIC SUBSTRUCTURE *** DØES NØT EXIST.

6516 *** USER INFØRMATIØN MESSAGE 6516, ALL MANUAL CØNNECTIØNS SPECIFIED ARE ALLØWABLE WITH RESPECT TØ TØLER.

6517 *** USER FATAL MESSAGE 6517, THE BASIC SUBSTRUCTURE *** REFERRED TØ BY A RELES BULK DATA CARD CANNØT BE FØUND IN THE PRØBLEM TABLE ØF CØNTENTS.

6518 *** USER FATAL MESSAGE 6518, ØNE ØF THE CØMPØNENT SUBSTRUCTURES HAS BEEN USED IN A PREVIØUS CØMBINE ØR REDUCE.

Each substructure may be used in only one CØMBINE or REDUCE. The previous CØMBINE or REDUCE must be DESTRØYed before it may be used again. An alternative is to EQUIV the substructure in question to a new substructure and then use the new substructure in the desired CØMBINE operation. See message 6105.

6519 *** USER FATAL MESSAGE 6519, REDUNDANT NAMES FØR RESULTANT PSEUDØSTRUCTURE HAVE BEEN SPECIFIED.

6520 *** USER FATAL MESSAGE 6520, REDUNDANT VALUES FØR TØLER HAVE BEEN SPECIFIED.

6521 *** USER INFØRMATIØN MESSAGE 6521, MØDULE CØMB1 SUCCESSFULLY CØMPLETED.

6522 *** USER FATAL MESSAGE 6522, THE BASIC SUBSTRUCTURE *** REFERRED TØ BY A CØNCT1 BULK DATA CARD CANNØT BE FØUND IN THE PRØBLEM TABLE ØF CØNTENTS.

6523 *** USER FATAL MESSAGE 6523, THE BASIC SUBSTRUCTURE *** REFERRED TØ BY A CØNCT BULK DATA CARD CANNØT BE FØUND IN THE PRØBLEM TABLE ØF CØNTENTS.

6524 *** USER FATAL MESSAGE 6524, NØ. ØF CØLUMNS ØF MATRIX E IN MYP3 IS UNEQUAL TØ NØ. ØF CØLUMNS ØF MATRIX B FØR A(T)B + E PRØBLEM.

This is a system error if the user is not using DMAP.

6525 *** USER INFØRMATIØN MESSAGE 6525, TRIPLE MULTIPLY TIME ESTIMATE FØR MYP3 = ********** SECØNDS.
(1)

6525 (2) *** USER INFØRMATIØN MESSAGE 6525, TRIPLE MULTIPLY TIME ESTIMATE FØR MYPAD - (AT * B)* A + E = ********** SECØNDS.

6525 (3) *** USER INFØRMATIØN MESSAGE 6525, TRIPLE MULTIPLY TIME ESTIMATE FØR MPYAD - AT * (B*A) + E = ********** SECØNDS.

6526 *** USER INFØRMATIØN MESSAGE 6526, THE CENTER MATRIX IS TØØ LARGE FØR IN-CØRE PRØCESSING. ØUT-ØF-CØRE PRØCESSING WILL BE PERFØRMED.

Issued by the MPYS module.

6528 *** USER FATAL MESSAGE 6528, INCØMPATIBLE LØCAL CØØRDINATE SYSTEMS HAVE BEEN FØUND. CØNNECTIØN ØF PØINTS IS IMPØSSIBLE, SUMMARY FØLLØWS.

6530 *** USER FATAL MESSAGE 6530, THE BASIC SUBSTRUCTURE *** REFERRED TØ BY A GTRAN CARD CANNØT BE FØUND IN THE PRØBLEM TABLE ØF CØNTENTS.

6531 *** USER FATAL MESSAGE 6531, NØ CØNNECTIØNS HAVE BEEN FØUND DURING THE AUTØMATIC CØNNECTIØN PRØCEDURE.

6533 *** USER FATAL MESSAGE 6533, ØPTIØNS PA HAS BEEN SPECIFIED BUT THE LØAP ITEM ALREADY EXISTS FØR SUBSTRUCTURE ***.

User must delete old appended loads before running with new appended loads.

6534 *** USER FATAL MESSAGE 6534, ØPTIØNS PA HAS BEEN SPECIFIED BUT THE STRUCTURE *** DØES NØT EXIST. YØU CANNØT APPEND SØMETHING TØ NØTHING.

6535 *** USER FATAL MESSAGE 6535, MØDULE CØMB1 TERMINATING DUE TØ ABØVE SUBSTRUCTURE CØNTRØL ERRØRS.

6536 *** USER FATAL MESSAGE 6536, MØDULE CØMB1 TERMINATING DUE TØ ABØVE ERRØRS IN BULK DATA.

6537 *** USER FATAL MESSAGE 6537, MØDULE CØMB1 TERMINATING DUE TØ ABØVE ERRØRS.

6551 *** USER FATAL MESSAGE 6551, MATRIX B IN MPY3 IS NØT SQUARE FØR A(T)BA + E PRØBLEM.

6552 *** USER FATAL MESSAGE 6552, NØ. ØF RØWS ØF MATRIX A IN MPY3 IS UNEQUAL TØ NØ. ØF RØWS ØF MATRIX B FØR A(T)B + E PRØBLEM.

6553 *** USER FATAL MESSAGE 6553, NØ. ØF RØWS ØF MATRIX A IN MPY3 IS UNEQUAL TØ NØ. ØF CØLUMNS ØF MATRIX B FØR A(T)BA + E PRØBLEM.

6554 *** USER FATAL MESSAGE 6554, NØ. CØLUMNS ØF MATRIX E IN MPY3 IS UNEQUAL TØ NØ. ØF CØLUMNS ØF MATRIX A FØR A(T)BA + E PRØBLEM.

6555 *** USER FATAL MESSAGE 6555, MATRIX E IN MPY3 IS NØT SQUARE FØR A(T)BA + E PRØBLEM.

6556 *** USER FATAL MESSAGE 6556, NØ. ØF RØWS ØF MATRIX E IN MPY3 IS UNEQUAL TØ NØ. ØF RØWS ØF MATRIX B FØR BA + E PRØBLEM.

6557 *** USER FATAL MESSAGE 6557, UNEXPECTED NULL CØLUMN ØF A(T) ENCØUNTERED.

Issued by MPY3 module.

6558 *** USER FATAL EMSSAGE 6558, INSUFFICIENT TIME REMAINING FØR MPY3 EXECUTIØN.

6559 *** USER FATAL MESSAGE 6559, NØ. ØF RØWS ØF MATRIX E IN MPY3 IS UNEQUAL TØ NØ. ØF CØLUMNS ØF MATRIX A FØR A(T)B + E PRØBLEM.

6601 *** USER FATAL MESSAGE 6601, REQUEST TØ REDUCE PSEUDØSTRUCTURE *** INVALID. DØES NØT EXIST ØN THE SØF.

15-18

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OF POOR QUALITY

6602 *** USER FATAL MESSAGE 6602, THE NAME *** CANNØT BE USED FØR THE REDUCED PSEUDØSTRUCTURE. IT ALREADY EXISTS ØN THE SØF.

6603 *** USER FATAL MESSAGE 6603, A BØUNDARY SET MUST BE SPECIFIED FØR A REDUCE ØPERATIØN.

6604 *** USER WARNING MESSAGE 6604, A BØUNDARY SET HAS BEEN SPECIFIED FØR ***, BUT IT IS NØT A CØMPØNENT ØF THE PSEUDØSTRUCTURE BEING REDUCED. THE BØUNDARY SET WILL BE IGNØRED.

6605 *** USER WARNING MESSAGE 6605, A BØUNDARY SET HAS BEEN SPECIFIED FØR *** BUT IT IS NØT A PHASE1 BASIC SUBSTRUCTURE. THE BØUNDARY SET WILL BE IGNØRED.

6606 *** USER FATAL MESSAGE 6606, BØUNDARY SET *** SPECIFIED IN CASE CØNTRØL HAS NØT BEEN DEFINED BY BULK DATA.

No BDYC bulk data has been entered.

6607 *** USER FATAL MESSAGE 6607, NØ BDYS ØR BDYS1 BULK DATA HAS BEEN INPUT TØ DEFINE BØUNDARY SET ***.

6608 *** USER FATAL MESSAGE 6608, THE REQUEST FØR BØUNDARY SET ***, SUBSTRUCTURE *** WAS NØT DEFINED.

6609 *** USER INFØRMATIØN MESSAGE 6609, NØ BØUNDARY SET HAS BEEN SPECIFIED FØR CØMPØNENT *** ØF PSEUDØSTRUCTURE ***. ALL DEGREES ØF FREEDØM WILL BE REDUCED.

6610 *** USER WARNING MESSAGE 6610, DEGREES ØF FREEDØM AT GRID PØINT *** CØMPØNENT SUBSTRUCTURE *** INCLUDED IN A BØUNDARY SET DØ NØT EXIST. REQUEST WILL BE IGNØRED.

6611 *** USER FATAL MESSAGE 6611, GRID PØINT *** SPECIFIED IN BØUNDARY SET *** FØR SUBSTRUCTURE *** DØES NØT EXIST.

6612 *** USER FATAL MESSAGE 6612, THE REDUCE ØPERATIØN REQUIRES SUBSTRUCTURE BULK DATA WHICH HAS NØT BEEN GIVEN.

6613 *** USER FATAL MESSAGE 6613, FØR RUN=GØ, THE REDUCED SUBSTRUCTURE *** MUST ALREADY EXIST.

6614 *** USER FATAL MESSAGE 6614, ILLEGAL ØR NØN-EXISTENT STRUCTURE NAME USED ABØVE.

6615 *** USER FATAL MESSAGE 6615, ILLEGAL BØUNDARY SET IDENTIFICATIØN NUMBER.

6616 *** USER INFØRMATIØN MESSAGE 6616, MØDULE REDUCE SUCCESSFULLY CØMPLETED.

6617 *** USER FATAL MESSAGE 6617, ØLDMØDES SET AND REQUESTED SØF ITEM DØES NØT EXIST. ITEM ***, SUBSTRUCTURE.

6618 *** USER FATAL MESSAGE 6618, ØLDMØDES NØT SET AND REQUESTED SØF ITEM MUST BE DELETED. ITEM ***, SUBSTRUCTURE ***.

6619 *** USER FATAL MESSAGE 6619, ØLDBØUND SET AND REQUESTED SØF ITEM DØES NØT EXIST. ITEM ***, SUBSTRUCTURE ***.

6620 *** USER FATAL MESSAGE 6620, ØLDBØUND NØT SET AND REQUESTED SØF ITEM MUST BE DELETED, ITEM ***, SUBSTRUCTURE ***.

6621 *** USER FATAL MESSAGE 6621, FIXED SET *** SPECIFIED IN CASE CØNTRØL HAS NØT BEEN DEFINED BY BULK DATA.

6622 *** USER WARNING MESSAGE 6622, A FIXED SET HAS BEEN SPECIFIED FØR ***, BUT IT IS NØT A CØMPØNENT ØF THE PSEUDØSTRUCTURE BEING PRØCESSED. THE FIXED SET WILL BE IGNØRED.

6623 *** USER FATAL MESSAGE 6623, SUBSTRUCTURE *** HAS DUPLICATE NAMES IN BDYC DATA SET ***.

6624 *** USER FATAL MESSAGE 6624, GRID PØINT *** SPECIFIED IN FIXED SET *** FØR SUBSTRUCTURE ***

DØES NØT EXIST.

6625 *** USER WARNING MESSAGE 6625, DEGREES ØF FREEDØM AT GRID PØINT *** CØMPØNENT SUBSTRUCTURE *** INCLUDED IN A FIXED SET DØ NØT EXIST. REQUEST WILL BE IGNØRED.

6626 *** USER FATAL MESSAGE 6626, NØ BDYS ØR BDYS1 BULK DATA HAS BEEN INPUT TØ DEFINE FIXED SET ***.

6627 *** USER FATAL MESSAGE 6627, NØ EIG* DATA CARDS SPECIFIED FØR SET ID ***, SUBSTRUCTURE ***.

6628 *** USER FATAL MESSAGE 6628, NØ EIGC ØR EIGR DATA CARDS SPECIFIED FØR SET ID ***, SUBSTRUCTURE ***.

6629 *** USER FATAL MESSAGE 6629, NØ EIGC DATA CARD SPECIFIED WITH EIGP DATA CARD SET ID ***, SUBSTRUCTURE ***.

6630 *** USER INFØRMATIØN MESSAGE 6630, FØR DRY ØPTIØN IN MØDAL REDUCE, INPUT DATA WILL BE CHECKED BUT NØ SØF TABLE ITEMS WILL BE CREATED.

6631 *** USER PØTENTIALLY FATAL MESSAGE 6631, IN CØMPLEX MØDAL REDUCE, ØNLY ØNE H TRANSFØRMATIØN MATRIX IS PRESENT ØN SØF FØR NØNSYMMETRIC REDUCTIØN.

6632 *** USER FATAL MESSAGE 6632, MØDULE ***, NASTRAN MATRIX FILE FØR I/Ø ØF SØF ITEM ***, SUBSTRUCTURE ***, IS PURGED.

6633 *** USER FATAL MESSAGE 6633, FØR SUBSTRUCTURE *** TØTAL NUMBER ØF MØDAL CØØRDINATES (***) IS LARGER THAN THE NUMBER ØF INTERIØR DØF (***).

6634 *** USER FATAL MESSAGE 6634, IN MØDULE MREDUCE WITH USER MØDE=2, THE CØNSTRAINT FØRCES MATRIX IS INCØMPATIBLE WITH THE NUMBER ØF MØDES (***).

6635 *** USER WARNING MESSAGE 6635, CDCØMP DECØMPØSITIØN FAILED ØN KII MATRIX FØR SUBSTRUCTURE ***.

6636 *** USER INFØRMATIØN MESSAGE 6636, NMAX AND RANGE SUBCØMMANDS ARE IGNØRED UNDER USERMØDE = TYPE 2.

6637 *** USER FATAL MESSAGE 6637, ØLDBØUND HAS BEEN SPECIFIED BUT THE BØUNDARY PØINTS FØR SUBSTRUCTURE *** HAVE BEEN CHANGED.

The boundary set data for the current problem is different from the boundary set data which created the UPRT SØF item for this substructure.

6638 *** USER FATAL MESSAGE 6638, IN MØDULE MREDUCE WITH USER MØDE=2, THE CØNSTRAINT FØRCES MATRIX (QSM) CANNØT BE PURGED.

6900 *** USER INFØRMATIØN MESSAGE 6900, LØADS HAVE BEEN SUCCESSFULLY APPENDED FØR SUBSTRUCTURE ***.

6901 *** USER INFØRMATIØN MESSAGE 6901, ADDITIØNAL LØADS HAVE BEEN SUCCESSFULLY MERGED FØR SUBSTRUCTURE.

6951 *** USER FATAL MESSAGE 6951, INSUFFICIENT CØRE TØ LØAD TABLES. IN MØDULE LØDAPP, CØRE = ***.

The total number of load sets times two must fit in core.

6952 *** USER FATAL MESSAGE 6952, REQUESTED SUBSTRUCTURE *** DØES NØT EXIST.

6953 *** SYSTEM FATAL MESSAGE 6953, A WRØNG CØMBINATIØN ØF LØAD VECTØRS EXISTS FØR SUBSTRUCTURE ***.

All load set IDs must be unique for each basic substructure.

6954 *** SYSTEM FATAL MESSAGE 6954, THE **** ITEM EXISTS BUT HAS NØ ASSØCIATED PVEC ITEM FØR SUBSTRUCTURE ********.

A load set table exists, but the load vectors have been removed.

6956 *** USER FATAL MESSAGE 6956, INSUFFICIENT TIME REMAINING FØR MØDULE LØDAPP, TIME LEFT = ********.

6.9 FUNCTIONAL MODULE MESSAGES (7001 THRU 8000)

7019 *** USER INFØRMATIØN MESSAGE 7019, MØDULE DSCHK IS EXITING FØR REASØN *** ØN ITERATIØN NUMBER ****** / PARAMETER VALUES ARE AS FØLØWS DØNE = **********, SHIFT = **********, DSEPSI = **************.

See Section 3.5.3 for a discussion of Rigid Format 4 output features.

8000 *** USER INFØRMATIØN MESSAGE 8000, MØDULE FLBMG TERMINATED DUE TØ ABØVE ERRØRS.

6.10 FUNCTIONAL MODULE MESSAGES (8001 THRU 9000)

8001 *** USER FATAL MESSAGE 8001, THERE MUST BE A FLUID/STRUCTURE BØUNDARY IN HYDRØELASTIC ANALYSIS.

8002 *** USER FATAL MESSAGE 8002, ELEMENT ID ********* ØN A CFLSTR CARD DØES NØT REFERENCE A VALID 2D STRUCTURAL ELEMENT.

8003 *** USER FATAL MESSAGE 8003, ELEMENT ID ********* ØN A CFLSTR CARD DØES NØT REFERENCE A VALID FLUID ELEMENT.

8004 *** USER FATAL MESSAGE 8004, ELEMENT ID ********* ØN A CFFREE CARD DØES NØT REFERENCE A VALID FLUID ELEMENT.

8005 *** USER FATAL MESSAGE 8005, BAD GEØMETRY DEFINED FØR STRUCTURAL ELEMENT *********.

8006 *** USER FATAL MESSAGE 8006, BAD GEØMETRY DEFINED FØR FACE ******** ØF FLUID ELEMENT ********.

8007 *** USER FATAL MESSAGE 8007, NØ FACE ØN FLUID ELEMENT ******** IS WITHIN 30 DEGREES ØF STRUCTURAL ELEMENT ********.

8008 *** USER FATAL MESSAGE 8008, THE DISTANCE BETWEEN FLUID ELEMENT ******** AND STRUCTURAL ELEMENT ******** IS GREATER THAN THE ALLØWED TØLERANCE.

8009 *** USER FATAL MESSAGE 8009, FACE ******** SPECIFIED FØR FLUID ELEMENT ******** IS AN ILLEGAL VALUE.

8010 *** SYSTEM FATAL MESSAGE 8010, LØGIC ERRØR IN SUBRØUTINE FLBEMA - CØDE ***.

8011 *** USER WARNING MESSAGE 8011, INSUFFICIENT CØRE TØ HØLD CØNTENTS ØF EQEXIN DATA BLØCK.

HYDROELASTIC USET PRINTOUT TERMINATED.

8012 *** USER FATAL MESSAGE 8012, FLUID ELEMENT ******** ØN A CFFREE CARD REFERENCES UNDEFINED GRAVITY ID ********.

8013 *** USER FATAL MESSAGE 8013, FLUID ELEMENT ******** ØN A CFLSTR CARD REFERENCES UNDEFINED GRAVITY ID ********.

8014 *** USER WARNING MESSAGE 8014, FLUID ELEMENT ******** AND STRUCTURE ELEMENT ******** ARE DISJØINT. CHECK CFLSTR CARDS.

8015 *** USER WARNING MESSAGE 8015, THE PURELY INCØMPRESSIBLE METHØD IS AVAILABLE ØNLY WITH THE DIRECT FØRMULATIØN.

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7. NASTRAN DICTIONARY

7.1 NASTRAN DICTIONARY

This section contains descriptions of mnemonics, acronyms, phrases, and other commonly used NASTRAN terms. The first column of the Dictionary contains the NASTRAN terms in alphabetical order. The second column contains a code indicating a general category for each term. The codes and categories, along with general references to the Programmer's Manual and User's Manual, are as follows:

Code	Category	General Reference
DBM	Data Block - Matrix	PM-2
DBML	Data Block - Matrix List	PM-2
DBS	Data Block - Substructure Item	UM-1.10
DBT	Data Block - Table	PM-2
EM	Executive Module	UM-5.7
FMA	Functional Module - Aero	PM-4
FMH	Functional Module - Heat	PM-4
FMM	Functional Module - Matrix Operation	UM-5.4
FMS	Functional Module - Structural	PM-4
FMSS	Functional Module - Substructuring	UM-5.9
FMU	Functional Module - Utility	UM-5.5
FMX	Functional Module - User	UM-5.6
IA	Input - Executive Control	UM-2.2
IB	Input - Bulk Data	UM-2.4
IC	Input - Case Control	UM-2.3
IS	Input - Substructure Control	UM-2.7
L	Rigid Format Label	UM-3
M	Miscellaneous	
NP	NASTRAN card parameter	UM-2.1
P	Parameter Name	UM-3
PH	Common Phrase or Term	
PU	Parameter set by user	UM-2.4

The third column of the Dictionary contains a definition or description of the terms given in the first column. References to the User's Manual are indicated by UM-i and the Programmer's Manual by PM-i, where i is the section number of the manual. References to particular rigid formats are indicated by D-i, H-i, or A-i where i is the rigid format number in the displacement, heat, and aero approaches, respectively.

NASTRAN DICTIONARY

A	P	Parameter value used to control utility module MATGPR print of A-set matrices.
ABFL	DBM	$[A_{b,f\ell}]$ - Hydroelastic boundary area factor matrix.
ABFLT	DBM	Transpose of $[A_{b,f\ell}]$.
ACCE	IC	Abbreviated form of ACCELERATIØN.
ACCE	IS	Acceleration output requests.
ACCELERATIØN	IC	Output request for acceleration vector. (UM-2.3, 4.2)
ACPT	DBT	Aerodynamic Connection and Property Data.
Active column	PH	Column containing at least one nonzero term outside the band.
ADD	FMM	Functional module to add two matrices together.
ADD	M	Parameter constant used in utility module PARAM.
ADD5	FMM	Functional module to add up to five matrices together.
ADR	FMS	Aerodynamic data recovery.
ADUMi	IB	Defines attributes of dummy elements 1 through 9.
AEFACT	IB	Used to input lists of real numbers for aeroelastic analysis.
AERØ	DBT	Aerodynamic Matrix Generation Data.
AERØ	IB	Gives basic aerodynamic parameters.
AERØF	IC	Aerodynamic force output request.
AERØFØRCE	IC	Requests frequency dependent aerodynamic loads on interconnection points in aeroelastic response analysis.
AJJL	DBML	Aerodynamic Influence Matrix List.
ALL	IC	Output request for all of a specified type of output.
ALLEDGE TICS	IC	Request tic marks on all edges of X-Y plot.
ALTER	IA	Alter statement for DMAP or rigid format.
ALWAYS	P	Parameter set to -1 by a PARAM statement.
AMG	FMA	Aerodynamic Matrix Generator.
AMP	FMA	Aerodynamic Matrix Processor.
AND	M	Parameter constant used in executive module PARAM.
AØUT$	M	Indicates restart with solution set output request.
APD	FMA	Aerodynamic pool distributor and element generator.
APP	IA	Control card which specifies approach (DISP, DMAP, HEAT or AERØ)
APP	P	Approach flag used for modules with several functions.

APPEND	M	File may be extended (see FILE).
ASDMAP	FMSS	Assemble substructure DMAP.
ASET	IB	Analysis set coordinate definition card.
ASET1	IB	Analysis set coordinate definition card.
AUTØ	IC	Requests X-Y plot of autocorrelation function.
AUTØ	DBT	Autocorrelation function table.
AXES	IC	Defines orientation of object for structure plot.
AXIC	DBT	Generated by Input File Processor 3 (IFP3) for axisymmetric conical shell problems.
AXIC	IB	Axisymmetrical conical shell definition card. When this card is present, most other bulk data cards may not be used.
AXIF	IB	Controls the formulation of a hydroelastic problem.
AXISYM$	M	Indicates restart with conical shell or hydroelastic elements.
AXISYMMETRIC	IC	Selects boundary conditions for axisymmetric shell problems or specifies the existence of hydroelastic fluid harmonics.
AXSLØT	IB	Controls the formulation of acoustic analysis problems.

B	PH	Upper semiband of matrix.
B2DD	DBM	$[B^2_{dd}]$ - Partition of direct input damping matrix.
B2PP	DBM	$[B^2_{pp}]$ - Direct input damping matrix for all physical points.
B2PP	IC	Selects direct input structural damping or thermal capacitance matrices.
B2PP$	M	Indicates restart with change in direct input damping matrices.
BAA	DBM	$[B_{aa}]$ - Partition of damping matrix.
BALL EDGE TICS	IC	Request for all edge tic marks to be plotted on lower frame of an X-Y plot.
BAR	IC	Requests structure plot for all bar elements.
BARØR	IB	Bar orientation default definition.
BASIC	IS	Basic substructure for output requests.
BBAR	PH	Lower semiband of matrix.
BDD	DBM	$[B_{dd}]$ - Damping matrix used in direct formulation of dynamics problems (D-7 thru D-9, A-11).
BDEBA	P	Parameter used to indicate equivalence of BDD and BAA.
BDPØØL	DBT	Hydroelastic boundary description table.
BDYC	IB	Combination of substructure boundary sets of retained degrees of freedom or fixed degrees of freedom for modes calculation.
BDYLIST	IB	Structure-fluid hydroelastic boundary definition.
BDYS	IB	Boundary set definition for substructuring.
BDYS1	IB	Alternate boundary set definition for substructuring.
BEGIN	EM	The first DMAP statement is always BEGIN.
BEGIN BULK	IB	Control card which marks the end of the case control deck. Cards following this card are assumed to be bulk data cards.
BETAD	PU	Factor in integration algorithm in transient heat transfer analysis.
BFF	DBM	$[B_{ff}]$ - Partition of damping matrix
BGG	DBM	$[B_{gg}]$ - Damping matrix generated by Structural Matrix Assembler.
BGPA	DBT	Basic Grid Point Definition Table - aerodynamics.
BGPDT	DBT	Basic Grid Point Definition Table.
BGSS	DBS	Basic grid point coordinates.
BHH	DBM	$[B_{hh}]$ - Partition of damping matrix.
BKLO	P	Constant parameter value used in functional module SDR2 in the Buckling Analysis (D-5) and Normal Modes with Differential Stiffness (D-13) Rigid Formats.

BKL1	P	Constant parameter value used in functional module SDR2 in the Buckling Analysis Rigid Format (D-5).
BLANK FRAMES	IC	Requests blank frames between structure plots (UM-4.1).
BLEFT TICS	IC	Request for left edge tic marks to be plotted on bottom frame of an X-Y plot.
BMG	GMS	Generates DMIG card images describing interconnection of fluid and structure.
BMTX	DBS	Viscous damping matrix.
BNN	DBM	$[B_{nn}]$ - Partition of damping matrix.
BØTH	IC	Bulk data echo option - Requests both unsorted and sorted printout of bulk data deck.
BØUNDARY	IS	Defines set of retained degrees of freedom.
BØV	P	Aerodynamic parameter equal to the reference semichord divided by velocity.
BPI	IC	Bits per inch - Plot tape density must be specified on control cards in addition to this data card. The required value will vary from one installation to another.
BQG	DBM	Single-point forces of constraint for a Buckling Analysis problem (D-5).
BRECØVER	IS	Basic Substructure Data Recovery.
BRIGHT TICS	IC	Request for right edge tick marks to be plotted on bottom frame for X-Y plot.
BSHH	DBM	Total modal damping matrix - h set.
BUCKLING	IA	Selects rigid format for buckling analysis.
BUCKLING	P	Constant parameter value used in functional module READ in the Buckling Analysis Rigid Format (D-5).
BUCKLING	P	Used in printing rigid format error messages for Buckling Analysis (D-5).
BUFFSIZE	NP	Defines the number of words in a GINØ buffer.
Bulk Data Deck	PH	One of the data decks necessary to run a problem under the NASTRAN system. This deck begins after the BEGIN BULK card and ends with the ENDDATA card, and contains the data of the mathematical model. The format of each bulk data card is fixed field, 8 or 16 columns for each value.

C	M	Used in parameter section of DMAP statement. Indicates that parameter is a constant.
C	PH	Symbol for active column in triangular decomposition ($\bar{C}$ used for active rows).
CAERØ1	IB	Aerodynamic panel element, doublet lattice theory.
CAERØ2	IB	Aerodynamic body element, doublet lattice theory.
CAERØ3	IB	Aerodynamic surface element, Mach box.
CAERØ4	IB	Aerodynamic macro element, strip theory.
CAERØ5	IB	Aerodynamic macro element, piston theory.
CALCØMP	IC	Request California Computer plotter.
CAMERA	IC	Selects one or both of the two cameras for the SC 4020 cathode ray tube electronic plotter. This information must usually also be given to the plotter operator on the run submittal slip which will vary from one installation to another. (UM-4)
CARDNØ	P	Parameter used to accumulate a count of all card output punched except the NASTRAN restart dictionary.
CASE	FMS	Extracts user request from CASECC for current loop in dynamics rigid formats (D-7 thru D-12).
Case Control Deck	PH	One of the data decks necessary to run a problem under the NASTRAN system. It contains cards which select particular data sets from the Bulk Data Deck, output request cards and titling information. Cards in this deck are free field.
CASECC	DBT	Case control data block.
CASEXX	DBT	Case control data block as modified by functional module CASE.
CASEYY	DBT	Appended case control data table.
CASEZZ	DBT	CASEYY reduced to ØFREQ list.
CAXIF2	IB	Acoustic core element connection definition card.
CAXIF3	IB	Acoustic triangular element connection definition card.
CAXIF4	IB	Acoustic quadrilateral element connection definition card.
CBAR	IB	Bar element connection definition card.
CCØNEAX	IB	Axisymmetrical conical shell element connection card.
CDAMP1	IB	Scalar damper connection definition card.
CDAMP2	IB	Scalar damper property and connection definition card.
CDAMP3	IB	Scalar damper connection definition card (connecting scalar points).
CDAMP4	IB	Scalar damper property and connection definition card (connecting scalar points).

CDUMi	IB	Defines definition card for dummy elements 1 through 9.
CEAD	FMS	Complex Eigenvalue Analysis - Displacement.
CEIF	P	Parameter used in SDR2 in Complex Eigenvalue Analysis (D-7 and D-10).
CEIGN	P	Parameter used in VDR in Complex Eigenvalue Analysis (D-7 and D-10).
CELAS1	IB	Scalar spring connection definition card.
CELAS2	IB	Scalar spring property and connection definition card.
CELAS3	IB	Scalar spring connection definition card (connecting scalar points).
CELAS4	IB	Scalar spring property and connecting definition card (connecting scalar points).
CEND	IA	The last card of the Executive Control Deck.
CFLUID2	IB	Fluid core element connection definition card.
CFLUID3	IB	Fluid triangular element connection definition card.
CFLUID4	IB	Fluid quadrilateral element connection definition card.
CHBDY	IB	Boundary element connection definition card for heat transfer analysis.
CHECK	IS	Checks contents of external file.
Checkpoint	PH	The process of writing selected data blocks onto the New Problem Tape for subsequent restarts.
CHEXA1	IB	Hexahedron element connection definition card - five tetrahedra.
CHEXA2	IB	Hexahedron element connection definition card - ten tetrahedra.
CHKPNT	EM	Checkpoint module.
CHKPNT	IA	Request for checkpoint execution.
CLAMA	DBT	Complex eigenvalue output table.
CLAMAL	DBT	Appended case control data table.
CLAMAL1	DBT	CLAMAL reduced to ØFREQ list.
CLEAR	IC	Causes all parameter values used for X-Y plots to be reset to their default values except plotter and the titles (UM-4.2).
CMASS1	IB	Scalar mass connection definition card.
CMASS2	IB	Scalar mass property and connection definition card.
CMASS3	IB	Scalar mass connection definition card (connecting scalar points).
CMASS4	IB	Scalar mass property and connection definition card (connecting scalar points).
CMETHØD	IC	Complex eigenvalue analysis method selection.

CMETHØD$	M	Indicates restart with change in complex eigenvalue analysis method selection.
CMPLEV	P	Parameter used in GKAD to indicate complex eigenvalue problem.
Cold Start	PH	A NASTRAN problem initiated at its logical beginning. A cold start will never use an Old Problem Tape but is may create a New Problem Tape for subsequent restarts.
CØLØR	IC	Selects ink color for table plotters (UM-4.1).
CØMBINE	IS	Combines sets of substructures.
CØMB1	FMSS	Substructure Combination, Step 1.
CØMB2	FMSS	Substructure Combination, Step 2.
CØMPØNENT	IS	Identifies component substructure for special processing.
CØNCT	IB	Specifies grid points and degrees of freedom for manually specified connectivities using substructuring - will be overridden by RELAS data.
CØNCT1	IB	Alternate specification of connectivities using substructuring.
CØND	EM	Conditional transfer.
CØNFIG	NP	Defines the model number of the computer system configuration for use in timing equations.
CØNM1	IB	Structural mass element connection definition card.
CØNM2	IB	Structural mass element connection definition card.
CØNNECT	IS	Defines sets for manually connected grids and releases.
CØNRØD	IB	Rod element property and connection definition card.
CØNRØD	IC	Requests structure plot for all CØNRØD elements.
CØNT	L	Continue if $[K_{oo}]$ is nonsingular.
CØNTINUE	L	Exit after last loop.
CØNTØUR	IC	Specifies displacement and stress contours to be drawn on structure plots.
CØPY	FMU	Generates a physical copy of a data block.
CØRD1C	IB	Cylindrical coordinate system definition (by grid point ID).
CØRD1R	IB	Rectangular coordinate system definition (by grid point ID).
CØRD1S	IB	Spherical coordinate system definition (by grid point ID).
CØRD2C	IB	Cylindrical coordinate system definition (by coordinates).
CØRD2R	IB	Rectangular coordinate system definition (by coordinates).
CØRD2S	IB	Spherical coordinate system definition (by coordinates).
CØSINE	IC	Indicates cosine boundary conditions for conical shell problem.

CØUPMASS	PU	Parameter used to request coupled mass.
CPBAR	PU	Selects couples mass option for BAR element.
CPHID	DBM	Complex Eigenvectors - solution set.
CPHIA	DBM	Complex eigenvector matrix, A-set.
CPHIH1	DBM	PHIHL reduced to ØFREQ list.
CPHIK	DBM	Complex eigenvector matrix, aerodynamic box points.
CPHIP	DBM	Complex Eigenvectors - physical set.
CPHIPA	DBM	Complex eigenvector matrix, PA-set.
CPHIPS	DBM	Complex eigenvector matrix, PS-set.
CPQDPLT	PU	Selects coupled mass option for QDPLT element.
CPQUAD1	PU	Selects coupled mass option for QUAD1 element.
CPQUAD2	PU	Selects coupled mass option for QUAD2 element.
CPRØD	PU	Selects coupled mass option for RØD and CØNRØD elements.
CPTRBSC	PU	Selects coupled mass option for TRBSC element.
CPTRIA1	PU	Selects coupled mass option for TRIA1 element.
CPTRIA2	PU	Selects coupled mass option for TRIA2 element.
CPTRPLT	PU	Selects coupled mass option for TRPLT element.
CPTUBE	PU	Selects coupled mass option for TUBE element.
CQDMEM	IB	Ouadrilateral membrane element connection definition card.
CQDMEM1	IB	Isoparametric quadrilateral membrane element connection definition card.
CQDMEM2	IB	Quadrilateral membrane element connection definition card.
CQDPLT	IB	Quadrilateral bending element connection definition card.
CQUAD1	IB	General Quadrilateral element connection definition card.
CQUAD2	IB	Homogeneous quadrilateral element connection definition card.
CRIGD1	IB	Rigid Element Connection.
CRIGD2	IB	Rigid Element Connection.
CRIGD3	IB	General rigid element connection.
CRIGDR	IB	Rigid Rod element connection.
CRØD	IB	Rod element connection definition card.
CREDUCE	IS	Complex modal reduction request.
CSHEAR	IB	Shear panel element connection definition card.

CSLØT3	IB	Triangular slot element connection definition card for acoustic analysis.
CSLØT4	IB	Quadrilateral slot element connection definition card for acoustic analysis.
CSTM	DBS	Local coordinate system transformation matrices.
CSTM	DBT	Coordinate System Transformation Matrices.
CSTMA	DBT	Coordinate System Transformation Matrices - Aerodynamics.
CTETRA	IB	Tetrahedron element connection definition card.
CTØRDRG	IB	Toroidal ring element connection card.
CTRAPRG	IB	Trapezoidal ring element connection card.
CTRBSC	IB	Basic bending triangular element connection definition card.
CTRIA1	IB	General triangular element connection definition card.
CTRIA2	IB	Homogeneous triangular element connection definition card.
CTRIARG	IB	Triangular ring element connection card.
CTRIM	IB	Linear strain triangular element connection.
CTRMRM	IB	Triangular membrane element connection definition card.
CTRPLT	IB	Triangular bending element connection definition card.
CTRPLT1	IB	Triangular element connection.
CTRSHL	IB	Triangular shell element connection.
CTUBE	IB	Tube element connection definition card.
CTWIST	IB	Twist panel element connection definition card.
CTYPE	PU	Defines the type of cyclic symmetry.
CURVLINESYMBØL	IC	Request to connect points with lines and/or to use symbols for X-Y plots.
CVISC	IB	Viscous damper element connection definition card.
CWEDGE	IB	Wedge element connection definition card.
CYCIØ	PU	A parameter which specifies the form of the input and output data using cyclic symmetry.
CYCSEQ	PU	A parameter which specifies the procedure for sequencing the equations in the solution set using cyclic symmetry.

D	P	Parameter value used to control utility module MATGPR print of solution set matrices.
DAREA	IB	Dynamic load scale card.
DAREAS	IB	Dynamic load scale card for substructuring.
Data Block	PH	Designates a set of data (matrix, table) occupying a file. A file is "allocated" to a data block and a data block is "assigned" to a file.
Data Pool File	PH	An executive file containing the ØSCAR and any data blocks pooled by the Executive Segment File Allocator (XSFA) module. The contents of this file are described within the data pool dictionary (DPL).
DDR	FMX	User dummy module.
DDR1	FMS	Dynamic Data Recovery - Phase 1.
DDR2	FMS	Dynamic Data Recovers - Phase 2.
DDRMM	FMS	Dynamic data recovery, matrix method.
Deck	PH	1. Job Control 2. Executive Control Deck 3. Substructure Control Deck 4. Case Control Deck 5. Bulk Data Deck
DECØMØPT	P	Controls type of arithmetic used in the decomposition for frequency-response problems.
DECØMP	FMM	To decompose a square matrix into upper and lower triangular factors.
Default	PH	Many NASTRAN data items have default values supplied by the system. For example, the default value for MAXLINES is 20000.
DEFØRM	IB	Enforced element deformation definition card.
DEFØRM	IC	Enforced element deformation set selection.
DEFØRM$	M	Indicates restart with change in enforced element deformation selection.
DEFØRMATIØN	IC	Indicates subcases to be used for deformed structure plots.
DELAY	IB	Dynamic load time delay card.
Delete	IB	Delete cards from Bulk Data Deck.
DELETE	IS	Deletes individual substructure items from the SØF.
DELTAPG	DBM	Incremental load vector in Piecewise Linear Analysis Rigid Format (D-6).
DELTAQG	DBM	Incremental vector of single point constraint forces in the Piecewise Linear Analysis Rigid Format (D-6).
DELTAUGV	DBM	Incremental displacement vector in the Piecewise Linear Analysis Rigid Format (D-6).

DENSITY	IC	Density of lines for SC 4020 plotter.
DENSITY	IC	Plot tape density must be specified to plotter operator on run submittal form and will vary from one installation to another (UM-4.1).
DESTRØY	IS	Removes all data referencing a component substructure.
DESTRY	P	Appended AJJL parameter.
DET	IB	Eigenvalue analysis method option - determinant (see EIGR, EIGB, EIGC).
DET	P	Scaled determinant $\|K_{oo}\|$, see NDET.
DIAGØNAL	FMU	Strips diagonal from matrix.
DIFF	P	Parameter used in the Piecewise Linear Analysis Rigid Format (D-6).
DIFFERENTIAL STIFFNESS	IA	Selects rigid format for static analysis with differential stiffness.
DIFFSTIF	P	Parameter used in the PRTPARM module in the Differential Stiffness Rigid Format (D-4).
DIRCEAD	P	Used in printing rigid format error messages for direct complex eigenvalue analysis (D-7).
DIRECT	P	Parameter used to indicate direct formulation of dynamics problems (D-7 thru D-9).
DIRECT CØMPLEX EIGENVALUES	IA	Selects rigid format for direct complex eigenvalue analysis.
DIRECT FREQUENCY RESPØNSE	IA	Selects rigid format for direct frequency and random response.
DIRECT TRANSIENT RESPØNSE	IA	Selects rigid format for direct transient response.
DIRFRRD	P	Used in printing rigid format error messages for direct frequency response.
DIRTRD	P	Used in printing rigid format error messages for direct transient response (D-9).
DISP	IA	Displacement approach to structural analysis.
DISP	IC	Abbreviated form of DISPLACEMENT.
DISP	IS	Displacement output request.
DISPLACEMENT	IC	Request for output of displacement vector or eigenvector. (UM-2.3, 4.2).
DIT	DBT	Direct Input Table.
DIV	P	Parameter constant used in utility module PARAM.
DLØAD	IB	Dynamics load assembly definition.
DLØAD	IC	Dynamic load set solution request.

DLØAD$	M	Indicates restart with change in dynamic load set request.
DLT	DBT	Dynamic Loads Table.
DM	DBM	[D] - Rigid body transformation matrix.
DMAP	IA	Approach option (direct Matrix Abstraction Program).
DMAP Instruction	PH	A statement in the DMAP Language.
DMAP Language	PH	Data block-oriented language used by the NASTRAN Executive System to direct the sequence and flow of modules to be executed.
DMAP Loop	PH	A DMAP sequence to be repeated, initiated with a LABEL DMAP instruction and terminated by a REPT DMAP instruction.
DMAP Module	PH	A module called by means of a DMAP instruction.
DMAP Sequence	PH	A set of DMAP instructions.
DMI	IB	Direct Matrix Input (data block is defined and used by user).
DMIAX	IB	Direct Matrix Input - Axisymmetric, used in dynamic rigid formats (D-7 thru D-12).
DMIG	IB	Direct Matrix Input - used in dynamic rigid formats (D-7 thru D-12).
Doublet Lattice	PH	Subsonic aerodynamic theory.
DPD	FMS	Dynamic Pool Distributor.
DPH	M	Data Pool Housekeeper - Executive routine.
DPHASE	IB	Dynamic load phase lead card.
DSØ	P	Parameter used in functional module SDR2 in the Differential Stiffness Rigid Format (D-4).
DS1	P	Parameter used in functional module SDR2 in the Differential Stiffness Rigid Format (D-4).
DSCØ	IC	Abbreviated form of DSCØEFFICIENT.
DSCØ$	M	Indicates restart with change in differential stiffness load factor.
DSCØEFFICIENT	IC	Selects loading factor for normal modes with differential stiffness.
DSCØSET	P	Differential Stiffness coefficient set number. Used in the Differential Stiffness Rigid Format (D-13).
DSFACT	IB	Differential stiffness factor set definition card.
DSMG1	FMS	Differential Stiffness Matrix Generator - Phase 1.
DSMG2	FMS	Differential Stiffness Matrix Generator - Phase 2.
DTI	IB	Direct Table Input - means by which user may directly input any table data block.

DUMMØD1	FMX	Dummy Module-1.
DUMMOD2	FMX	Dummy Module-2.
DUMMØD3	FMX	Dummy Module-3.
DUMMOD4	FMX	Dummy Module-4.
Dummy Element	PH	Provision for user to insert additional finite element into the NASTRAN element library.
DUMP	IS	Copies the entire SØF to an external file.
Dump	PH	Printed output of contents of all, or a portion, of main memory at some point in the problem solution.
DYNAMICS	DBT	Generated by the Input File Processor (IFP) for Real Eigenvalue, Buckling, or any of the Dynamics Rigid Formats (D-3, D-5 and D-7 thru D-12).
D1JE	DBM	Downwash factors due to extra points - real.
D2JE	DBM	Downwash factors due to extra points - complex.
D1JK	DBM	Real part of downwash matrix.
D2JK	DBM	Imaginary part of downwash matrix.

E	P	Parameter value used by MATGPR to print matrices associated with extra points.
ECHØ	IC	Output request statement for echo of bulk data.
ECPT	DBT	Element Connection and Properties Table.
ECPTNL	DBT	Nonlinear subset of the ECPT. This data block is used only in the Piecewise Linear Analysis Rigid Format (D-6).
ECPTNL1	DBT	Updated version of the ECPTNL data block. Used only in the Piecewise Linear Anslysis Rigid Format (D-6).
ECPTNLPG	P	Error flag for the Piecewise Linear Analysis Rigid Format (D-6). If all elements in a piecewise linear analysis problem are linear, this error flag is set and a DMAP exit occurs.
ECT	DBT	Element Connection Table.
ECTA	DBT	Element Connection Table - Aerodynamics.
EDIT	IS	Removes data from SØF file.
EDT	DBT	Enforced Deformation Table - generated by Input File Processor.
EED	DBT	Eigenvalue Extraction Data table (D-3, D-5, D-7, D-10, D-11, D-12, D-13, D-15, A-10, A-11).
EIGB	IB	Real eigenvalue extraction data for buckling analysis (D-5).
EIGC	IB	Complex eigenvalue extraction data card (D-7 and D-10).
EIGP	IB	Complex eigenvalue pole definition card (D-7 and D-10).
EIGR	IB	Real eigenvalue extraction data for normal mode analysis (D-3, D-10 thru D-13, D-15, A-10).
EIGVS	P	Number of eigenvalues found by CEAD module.
ELEMENTS	IC	Used in element set definition for structure plot.
ELFØRCE	IC	Requests the forces in a set of structural elements or the temperature gradients and fluxes in a set of structural or heat elements in heat transfer.
ELSETS	DBT	Element plot set connection tables.
ELSETSA	DBT	Data block ELSETS, extended to include generated aerodynamic elements.
ELSTRESS	IC	Request for output of element stresses. (UM-2.3, 4.2).
END	EM	The last DMAP statement is always END.
END	IA	END is the last statement in all DMAP sequences.
ENDALTER	IA	Last card of alter packet.
ENDDATA	IB	End of Bulk Data Deck.

ENDSUBS	IS	Terminates the Substructure Control Deck.
ENERGY	IS	Modal energies output requests.
EØF	PH	End-of-File.
EPØINT	IB	Extra point definition card - used in dynamics problems only.
EPSHT	PU	Used in convergence tests for nonlinear heat transfer analysis.
EPSILØN SUB E (ϵ_e)	PH	Error ratio computed in SSG3. $\epsilon_e = \epsilon_\ell$ if the referenced load is $\{P_\ell\}$ and $\epsilon_e = \epsilon_0$ if the referenced load is $\{P_0\}$. See section 3.2 for mathematical definition of ϵ_0 and ϵ_ℓ.
EPSIØ	PU	A parameter to test the convergence of iterated differential stiffness.
EPT	DBT	Element Property Table - output by Input File Processor.
EQAERØ	DBT	Equivalence between external points and scalar index values - Aerodynamics.
EQDYN	DBT	Equivalence of internal and external indices - dynamics.
EQEXIN	DBT	Equivalence of internal and esternal indices.
EQSS	DBS	External grid point and internal point equivalence data.
EQUIV	EM	Equivalence data blocks.
EQUIV	IS	Creates a new equivalent substructure.
Equivalence	PH	Data blocks are considered equivalenced when references to their equivalent names access the same physical data file.
ERRØR1	L	Label used when rigid format errors are detected.
ERRØR2	L	Label used when rigid format errors are detected.
ERRØR3	L	Label used when rigid format errors are detected.
ERRØR4	L	Label used when rigid format errors are detected.
ERRØR5	L	Label used when rigid format errors are detected.
ERRØR6	L	Label used when rigid format errors are detected.
ESE	IC	Request for element strain energy output.
EST	DBT	Element Summary Table.
ESTL	DBT	Element Summary Table for Linear elements. Used only in the Piecewise Linear Analysis Rigid Format (D-6).
ESTNL	DBT	Element Summary Table for Nonlinear elements. Used only in the Piecewise Linear Analysis Rigid Format (D-6).
ESTNL1	DBT	Updated version of the ESTNL data block. Used only in the Piecewise Linear Analysis Rigid Format (D-6).
EVEC	DBM	Partitioning vector. D-set to A and E.

EXCEPT	IC	Forms exceptions to string of values in set declarations.
EXCLUDE	IC	Used in set definition for structure plots.
Executive	PH	1. Executive Control Deck 2. NASTRAN Executive System
Executive Control Deck	PH	One of the data decks necessary to run a problem under the NASTRAN system. This deck begins with the ID card and ends with the CEND card. Among other things, cards in this deck select the solution approach and rigid format to be used, limit the execution time, and control checkpointing and restart.
Executive System	PH	The Executive System initiates a NASTRAN problem solution via the Preface, allocates files to data blocks during problem solution, controls the sequence of the modules to be executed, and provides for problem restart capability.
EXIØ	FMSS	External input/output for the SØF.
EXIT	EM	Program termination DMAP statement.
External Sort	PH	Order of grid, scalar and extra points determined by the user's numerical order of point identification.
Extra Point	PH	A "point" which is defined on a EPØINT bulk data card. An extra point has no geometrical coordinates, defines only one degree of freedom of the model and is used only in dynamics solutions.

F	P	Parameter value used by MATGPR to print F-set matrices.
FA1	FMS	Flutter Analysis - Phase 1.
FA2	FMS	Flutter Analysis - Phase 2.
FBS	FMM	Forward and Backward Substitution
FE	P	Parameter used by MATGPR to print out FE-set matrices.
FEER	IB	Fast Eigenvalue Extraction Routine eigensolution method.
FIAT	M	File Allocation Table. Core resident executive table where data block names, status of the data blocks (assigned to a file, purged, equivalenced, etc.) and trailer for the data blocks are stored.
FILE	EM	Defines special data block characteristics to DMAP compiler.
FILE	IA	Term appearing on the checkpoint dictionary cards indicating the file number (internal) associated with a particular data block.
FILE	M	The FILE DMAP statement specifies data block characteristics such as TAPE, SAVE, and APPEND.
FILE	PH	Designates an auxiliary storage area or unit.
FILES	NP	Declares the NASTRAN permanent files as disk files.
FIND	IC	Selects parameters for structure plot.
FINIS	L	Label used in all displacement rigid format DMAPs to terminate execution of DMAP.
Finite Element	PH	Idealized unit of a structural model that represents the distributed elastic properties of a structure.
FIST	M	File Status Table. Core resident executive table where internal file names and pointers to the FIAT, pertaining only to the module being executed, are stored.
FIXED	IS	Defines set of constrained degrees of freedom for modes calculation.
FLAGS	IA	Term appearing on the checkpoint dictionary cards indicating the status of a data block (equivalenced or not).
FLFACT	IB	Specifies densities, Mach numbers and frequencies.
FLIST	DBT	Flutter Control Table.
FLØØP	P	Flutter loop counter/control.
FLSYM	IB	Structural symmetry definition card for use in hydroelastic problems.
FLUID	IC	Indicates hydroelastic harmonic degrees of freedom.
FLUTTER	IB	Defines flutter data.
FMETHØD	IC	Flutter Analysis Method Selection.

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FMØDE	P	Mode number of first mode selected by user in modal dynamics formulations.
FØL	DBT	Frequency response output frequencies.
FØRCE	IB	Static load definition (vector).
FØRCE	IC	Request for output of element forces.
FØRCE1	IB	Static load definition (magnitude and two grid points).
FØRCE2	IB	Static load definition (magnitude and four grid points).
FØRCEAX	IB	Static load definition for conical shell problem.
FREEPT	IB	Defines point on a free surface of a fluid for output purposes.
FREQ	IB	Frequency list definition.
FREQ$	M	Indicates restart with change in frequencies to be solved.
FREQ1	IB	Frequency list definition (linear increments).
FREQ2	IB	Frequency list definition (logarithmic increments).
FREQRESP	P	Parameter used in SDR2 to indicate a frequency response problem.
FREQUENCY	IC	Selects the set of frequencies to be solved in frequency response problems.
FREQY	P	Selects between frequency and transient in aeroelastic response.
FRL	DBT	Frequency Response List.
FRLG	FMA	Frequency response load generator.
FRQSET	P	Used in FRRD to indicate user selected frequency set.
FRRD	FMS	Frequency and Random Response - Displacement approach.
FRRD2	FMA	Frequency response, with aerodynamic matrix capability.
FSAVE	DBT	Flutter Storage Save Table.
FSLIST	IB	Defines a free surface of a fluid in a hydroelastic problem.
Functional Module	PH	An independent group of subroutines that perform a structural analysis function.

G	PU	1. Parameter used by MATGPR to print G-set matrices. 2. Parameter used to input uniform structural damping coefficient (D-7 thru D-9).
GEI	DBT	General Element Input.
GENEL	IB	General element definition.
GEØM1	DBT	Geometric data input table - generated by the Input File Processor.
GEØM2	DBT	Connection input table - generated by the Input File Processor.
GEØM3	DBT	Static load and temperature input table - generated by the Input File Processor.
GEØM4	DBT	Displacement sets definition input table - generated by the Input File Processor.
GI	FMA	Geometry Interpolator.
GIMS	DBS	G transformation matrix for interior points from a modal reduction.
GINØ	M	General input/output. GINØ is a collection of subroutines which is the input/output control system for NASTRAN.
GINØ Buffer	PH	Storage reserved in open core for each GINØ file opened. The size of the buffer is machine dependent.
GINØ File Number	PH	File number used internally in DMAP modules to access data blocks.
GIV	IB	Eigenvalue analysis method option - Givens (see EIGR).
GKAD	FMS	General [K] Assembler - Direct.
GKAM	FMS	General [K] Assembler - Modal.
GM	DBM	$[G_m]$ - multipoint constraint transformation matrix.
GMD	DBM	$[G_m^d]$ - multipoint constraint transformation matrix used in dynamic analysis.
GNFIAT	M	Generate FIAT. The preface routine which generates the initial FIAT.
GØ	DBM	$[G_o]$ - structural matrix partitioning transformation matrix.
GØD	DBM	$[G_o^d]$ - structural matrix partitioning transformation matrix used in dynamic analysis.
GPARAM	IS	Specifies structural damping parameter.
GP1	FMS	Geometry Processor - part 1.
GP2	FMS	Geometry Processor - part 2.
GP3	FMS	Geometry Processor - part 3.
GP4	FMS	Geometry Processor - part 4.

GPCT	DBT	Grid Point Connection Table.
GPDT	DBT	Grid Point Definition Table.
GPFØRCE	IC	Requests grid point force balance output.
GPI	M	General Problem Initialization (see XGPI).
GPL	DBT	Grid Point List.
GPLA	DBT	Grid Point List - Aerodynamics.
GPLD	DBT	Grid Point List used in dynamic analysis.
GPSETS	DBT	Grid point plot sets.
GPSETSA	DBT	Data block GPSETS, extended to include generated aerodynamic grid points.
GPSP	FMS	Grid Point Singularity Processor.
GPST	DBT	Grid Point Singularity Table.
GPTT	DBT	Grid Point Temperature Table.
GPWG	FMS	Grid Point Weight Generator.
GRAV	IB	Gravity vector definition card.
GRDEQ	PU	Selects the grid point about which equilibrium will be checked.
GRDPNT	PU	Used in all displacement rigid formats to specify execution of the grid point weight generator (GPWG) by the user. A positive value references a grid point of the structural model. A value of zero indicates the origin of the basic coordinate system.
GRDSET	IB	Grid point default definition card.
GRID	IB	Grid point definition card.
Grid Point	PH	A point in Euclidean 3-dimensional space defined on a GRID bulk data card. A grid point defines 6 degrees of freedom, 3 translational and 3 rotational.
GRID PØINTS	IC	Used in set definition for structure plots.
GRIDB	IB	Grid point definition card for hydroelastic model.
GRIDF	IB	Grid point definition card for axisymmetric fluid cavity.
GRIDS	IB	Grid point definition card for slotted acoustic cavity.
GTKA	DBM	Aerodynamic transformation matrix - k-set to a-set.
GTRAN	IB	Redefines the output coordinate system grid point displacement sets.
GUST	FMA	Calculates loads due to gust.
GUST	IB	Defines stationary vertical gust.
GUST	IC	Aerodynamic gust input request.
GUSTAERØ	PU	Requests matrices used only in gust calculations to be computed.

HARMONICS	IC	Controls number of harmonics output in axisymmetric shell problems and hydroelastic problems.
HB2DD	DBM	$[B^2_{dd}]$ - Partition of heat capacity matrix.
HB2PP	DBM	$[B^2_{dd}]$ - Partition of heat capacity matrix.
HBAA	DBM	$[B_{aa}]$ - Partition of heat capabity matrix.
HBDD	DBM	$[B_{dd}]$ - Partition of heat capacity matrix.
HBFF	DBM	$[B_{ff}]$ - Partition of heat capacity matrix.
HBGG	DBM	$[B_{gg}]$ - Heat capacity matrix.
HBNN	DBM	$[B_{nn}]$ - Partition of heat capacity matrix.
HDLT	DBT	Dynamic loads table for heat transfer analysis.
Header record	PH	Initial record of a data block. Typically a header record contains only 2 BCD words, the alphanumeric name of the data block.
HEAT	IA	Selects heat transfer analysis on APProach card.
HESS	IB	Upper Hessenberg eigenvalue extraction method.
HFREQ	PU	High frequency limit for modal formulation of dynamics problems (D-10 thru D-12, A-10, A-11).
HICØRE	NP	Defines the amount of open core available to the user on the UNIVAC 1100 series.
HK2DD	DBM	$[K^2_{dd}]$ - Partition of heat conductivity matrix.
HK2PP	DBM	$[K^2_{pp}]$ - Partition of heat conductivity matrix.
HKAA	DBM	$[K_{aa}]$ - Partition of heat conductivity matrix.
HKDD	DBM	$[K_{dd}]$ - Partition of heat conductivity matrix.
HKFF	DBM	$[K_{ff}]$ - Partition of heat conductivity matrix.
HKFS	DBM	$[K_{fs}]$ - Partition of heat conductivity matrix.
HKGG	DBM	$[K_{gg}]$ - Heat conductivity matrix, including estimated linear component of radiation.
HKGGX	DBM	$[K^x_{gg}]$ - Heat conductivity matrix.
HKNN	DBM	$[K_{nn}]$ - Partition of heat conductivity matrix.
HLFT	DBS	Left side H transformation matrix from unsymmetric CREDUCE operation.
HØEF1X	DBT	Heat flux output table for CHBDY elements.
HØRG	DBS	H or G transformation matrix.
HPDØ	DBM	$\{P^o_d\}$ - Partition of dynamic load vector.
HPDT	DBM	$\{P^t_d\}$ - Partition of dynamic load vector.

HPPØ	DBM	$\{P_p^o\}$ - Partition of dynamic load vector.
HPSØ	DBM	$\{P_s^o\}$ - Partition of dynamic load vector.
HQGE	DBM	$[Q_{ge}]$ - Element radiation flux matrix for heat transfer analysis.
HRAA	DBM	$[R_{aa}]$ - Partition of radiation matrix.
HRDD	DBM	$[R_{dd}]$ - Partition of radiation matrix.
HRFF	DBM	$[R_{ff}]$ - Partition of radiation matrix.
HRGG	DBM	$[R_{gg}]$ - Radiation matrix for heat transfer analysis.
HRNN	DBM	$[R_{nn}]$ - Partition of radiation matrix.
HSLT	DBT	Static heat flux table.
HTØL	DBT	List of output time steps for heat transfer.

IC	IC	Transient analysis initial condition set selection.
ID	IA	The first card of any data deck is the identification (ID) card. The two data items on this card are BCD values.
IFP	EM	Input File Processor. The preface module which processes the sorted Bulk Data Deck and outputs various data blocks depending on the card types present in the Bulk Data Deck.
IFP1	EM	Input File Processor 1. The preface module which processes the Case Control Deck and writes the CASECC, PCDB and XYCDB data blocks.
IFP3	EM	Input File Processor 3. The preface module which processes bulk data cards for a conical shell problem.
IFP4	EM	Input File Processor 4. The preface module which processes bulk data cards for a hydroelastic problem.
IFT	FMA	Inverse Fourier transformation.
IFTM	PU	A parameter which selects the method for integration of the Inverse Fourier Transform.
IFTSKP	L	Used to skip IFT module.
IMAG	IC	Output request for real and imaginary parts of some quantity such as displacement, load, single point force of constraint element force, or stress.
IMPL	P	Parameter constant used in executive module PARAM.
INCLUDE	IC	Used in set definition for structure plots.
INERTIA	P	Used in printing rigid format error messages for Static Analysis with Inertia Relief (D-2).
INERTIA RELIEF	IA	Selects rigid format for static analysis with inertia relief.
INPT	M	A reserved NASTRAN physical file which must be set up by the user when used.
INPUT	FMU	Generates most of bulk data for selected academic problems.
Input Data Block	PH	A data block input to a module. An input data block must have been previously output from some module and may not be written on.
Input Data Cards	PH	The card input data to the NASTRAN system are in 3 sets, the Executive Control Deck, the Case Control Deck, and the Bulk Data Deck.
INPUTT1	FMU	Reads data blocks from GINØ-written user tapes.
INPUTT2	FMU	Reads data blocks from FØRTRAN-written user tapes.
INPUTT3	FMX	Auxiliary input file processor.
INPUTT4	FMX	Auxiliary input file processor.
Internal Sort	PH	Same order as external sort except when SEQGP or SEQEP bulk data cards are used to change the sequence.

INV	IB	Inverse power eigenvalue analysis option - specified on EIGR, EIGB or EIGC cards.
IRES	PU	Causes printout of residual vectors in statics rigid formats when set nonnegative via a PARAM bulk data card. (D-1, D-2, D-4, D-5, D-6).
ISTART	PU	A parameter which causes the alternate starting method to be used in transient analysis.
ITEMS	IS	Specifies data items to be copied in or out.

JUMP	EM	Unconditional transfer DMAP statement.
JUMPPLØT	P	Parameter used by structure plotter modules PLTSET and PLØT.

K2DD	DBM	$[K^2_{dd}]$ - Partition of direct input stiffness matrix.
K2DPP	DBM	$[K^{2d}_{pp}]$ - Direct input stiffness matrix for all physical points from bulk data deck.
K2PP	DBM	$[K^2_{pp}]$ - Direct input stiffness matrix for all physical points.
K2PP	IC	Selects direct input structural stiffness or thermal conductance matrices.
K2PP$	M	Indicates restart with change in direct input stiffness matrices.
K2XPP	DBM	$[K^{2x}_{pp}]$ - Direct input stiffness matrix excluding hydroelastic boundary stiffness matrix.
K4AA	DBM	$[K^4_{aa}]$ - Partition of structural damping matrix.
K4FF	DBM	$[K^4_{ff}]$ - Partition of structural damping matrix.
K4GG	DBM	$[K^4_{gg}]$ - Structural damping matrix generated by Structural Matrix Assembler
K4MX	DBS	Structural damping matrix.
K4NN	DBM	$[K^4_{nn}]$ - Partition of structural damping matrix.
KAA	DBM	$[K_{aa}]$ - A-set stiffness matrix.
KAAB	DBM	$[\overline{K}_{aa}]$ - Partition of stiffness matrix.
KBFS	DBM	$[K^b_{fs}]$ - Partition of combination of elastic stiffness matrix matrix and differential stiffness matrix.
KBFL	DBM	$[K_{b,f\ell}]$ - Hydroelastic boundary stiffness matrix.
KBLL	DBM	$[K^b_{\ell\ell}]$ - Combination of elastic stiffness and differential stiffness used in static analysis with differential stiffness.
KBSS	DBM	$[K^b_{ss}]$ - Partition of combination of stiffness matrix and differential stiffness matrix.
KDAA	DBM	$[K^d_{aa}]$ - Partition of differential stiffness matrix.
KDAAM	DBM	$-[K^d_{aa}]$ - Differential stiffness matrix used in formulation of buckling problems (D-5).
KDAMP	PU	-1 for structural damping, +1 for viscous.
KDD	DBM	$[K_{dd}]$ - Stiffness matrix used in direct formulation of dynamics problems (D-7 thru D-9).
KDEK2	P	Parameter indicating equavalence of KDD and K2DD.
KDEKA	P	Parameter indicating equavalence of KDD and KAA.
KDFF	DBM	$[K^d_{ff}]$ - Partition of differential stiffness matrix.
KDFS	DBM	$[K^d_{fs}]$ - Partition of differential stiffness matrix.
KDGG	DBM	$[K^d_{gg}]$ - Differential stiffness matrix prepared by Differential Stiffness Matrix Generator.
KDNN	DBM	$[K^d_{nn}]$ - Partition of differential stiffness matrix.

KDSS	DBM	$[K^d_{ss}]$ - Partition of differential stiffness matrix.
KE	PH	Flutter analysis method.
KEF	DBM	$[K_{ff}]$ - Partition of stiffness matrix.
KFS	DBM	$[K_{fs}]$ - Partition of stiffness matrix.
KGG	DBM	$[K_{gg}]$ - Stiffness matrix generated by Structural Matrix Assembler.
KGGL	DBM	$[K^{\ell}_{gg}]$ - Stiffness matrix for linear elements. Used only in the Piecewise Linear Analysis Rigid Format (D-6).
KGGLPG	P	Purge flag for KGGL matrix. If set to -1, it implies that there are no linear elements in the structural model. (D-6).
KGGNL	DBM	$[K^{n\ell}_{gg}]$ - Stiffness matrix for the nonlinear elements. Used in the Piecewise Linear Analysis Rigid Format only.
KGGSUM	DBM	Sum of KGGNL and KGGL. Used in the Piecewise Linear Analysis Rigid Format only. (D-6).
KGGX	DBM	$[K^x_{gg}]$ - Stiffness matrix excluding general elements.
KGGXL	DBM	$[K^{x\ell}_{gg}]$ - Stiffness matrix for linear elements (excluding general elements). Used in the Piecewise Linear Rigid Format only. (D-6).
KGGY	DBM	$[K^y_{gg}]$ - Stiffness matrix of general elements.
KHH	DBM	$[K_{hh}]$ - Stiffness matrix used in modal formulation of dynamics problems (D-10 thru D-12).
KINDEX	PU	A parameter which specifies a single value of the harmonic index using cyclic symmetry.
KLL	DBM	$[K_{\ell\ell}]$ - Stiffness matrix used in solution of problems in static analysis (D-1, D-2, D-4, D-5, D-6).
KLR	DBM	$[K_{\ell r}]$ - Partition of stiffness matrix.
KMAX	PU	A parameter which specifies the maximum value of the harmonic index using cyclic symmetry.
KMTX	DBS	Stiffness matrix.
KNN	DBM	$[K_{nn}]$ - Partition of stiffness matrix.
KØA	DBM	$[K_{oa}]$ - Stiffness matrix partition.
KØØ	DBM	$[K_{oo}]$ - Partition of stiffness matrix.
KRR	DBM	$[K_{rr}]$ - Partition of stiffness matrix.
KSS	DBM	$[K_{ss}]$ - Partition of stiffness matrix.
KXHH	DBM	Total modal stiffness matrix - h-set.

L	P	Parameter value used by MATGPR to print L-set matrices.
LABEL	EM	DMAP location.
LABEL	IC	Defines third line of titles to be printed on each page of printer output. Also used on plots.
LABEL	IC	Requests identification of grid points and/or elements on structure plot.
LAMA	DBT	Real eigenvalues
LAMS	DBS	Eigenvalue data from modal reduce operation.
LAMX	FMU	Edit or generate data block, LAMA.
LBLi	L	A label used in displacement approach rigid formats where i represents one or more characters used to form unique labels.
LBLL	DBM	$[L^b_{\ell\ell}]$ - Lower triangular factor of $[K^b_{\ell\ell}]$.
LEFT TICS	IC	Request for tic marks to be plotted on left hand edge of frame for X-Y plots.
LFREQ	PU	Low frequency limit for modal formulation of dynamics problems (D-10 thru D-12).
LGPWG	L	Label used in conjunction with the Grid Point Weight Generator.
LINE	IC	Number of data lines printed per page of printer output. It should be set to 50 for 11 x 17 inch paper, and to 35 for 8 1/2 x 17 inch paper.
LIST	IA	Used to list the problem deck from UMF or copy the problem deck from UMF onto NUMF and list it.
LLL	DBM	$[L_{\ell\ell}]$ - Lower triangular factor of $[K_{\ell\ell}]$.
LMØDES	PU	Number of lowest modes for modal formulation of dynamics problems (D-10 thru D-12).
LMTX	DBS	Decomposition product of REDUCE operation.
LØAD	1B	Statis load combination definition.
LØAD	IC	Selects statis structural loading condition or heat power and/or flux.
LØADC	IB	Defines loading conditions for static analysis using sybstructuring.
LØAD$	M	Indicates restart with change in static load set request.
LØAP	DBS	Load set identification numbers for appended load vectors.
LØDS	DBS	Load set identification numbers.
LØGARITHMIC	IC	Requests logarithmic scales for X-Y plots.
LØGPAPER	IC	Requests logarithmic paper for X-Y plots.
LØØ	DBM	$[L_{oo}]$ - Lower triangular factor of $[K_{oo}]$.

LØØP1$	M	Indicates looping problem in modified restart. (PM-4.3.7.1)
LØØPBGN	L	Signifies the beginning of the Piecewise Linear Analysis Rigid Format DMAP Loop. (D-6).
LØØPEND	L	Signifies the end of the Piecewise Linear Analysis Rigid Format DMAP loop. (D-6).
LØØP$	M	Indicates looping problem in modified restart. (PM-4.3.7.1)
LØØPTØP	L	Top of rigid format loop.
LØWER TICS	IC	Request for tic marks to be plotted on bottom edge of frame for X-Y plots.
LSING	L	Used if $[K_{oo}]$ is singular.
LUSET	P	Order of USET.
LUSETA	P	Number of degrees of freedom in the pa displacement set.
LUSETD	P	Order of USETD.

M	P	Parameter value used by MATGPR to print M-set matrices.
M2DD	DBM	$[M^2_{dd}]$ - Partition of direct input mass matrix.
M2DPP	DBM	$[M^{2d}_{pp}]$ - Direct input mass matrix for all physical points from Bulk Data Deck.
M2PP	DBM	$[M^2_{pp}]$ - Direct input massmatrix for all physical points.
M2PP	IC	Direct input mass matrix selection.
M2PP$	M	Indicates restart with change in direct input mass matrices.
MAA	DBM	$[M_{aa}]$ - Partition of mass matrix.
MACH	PU	Velocity divided by speed of sound.
MASS	IB	Eigenvector normalization option - used on EIGR card.
MAT1	IB	Material definition card for isotropic material.
MAT2	IB	Material definition card for anisotropic material.
MAT3	IB	Material definition card for orthotropic material.
MAT4	IB	Thermal material definition card for isotropic material.
MAT5	IB	Thermal material definition card for anisotropic material.
MATGPR	FMU	Utility module for printing matrices with Grid Point Identification.
MATPØØL	DBT	Grid point oriented direct input matrix data pool, output by Input File Processor and used by functional module MTRXIN.
MATPRN	FMU	Utility module for printing matrices.
MATPRT	FMU	Utility module for printing matrices with geometric grid points.
Matrix Control Block	PH	A seven word array, the first word is a GINØ file number, and words 2 through 7 comprise a matrix trailer.
Matrix Data Block	PH	A data block is classified as a matrix if and only if it is generated by one of the NASTRAN matrix packing routines, PACK or BLDPK.
Matrix Decomposition	PH	A factorization of a matrix K so that K = LU where L is a unit lower triangular matrix and U is an upper triangular matrix.
MATS1	IB	Specifies table references for stress-dependent material properties.
MATT1	IB	Specifies table references for temperature-dependent isotropic material properties.
MATT2	IB	Specifies table references for temperature-dependent anisotropic material properties.
MATT3	IB	Specifies table references for temperature-dependent orthotropic material properties.
MATT4	IB	Specifies table references for temperature-dependent isotropic, thermal material properties.

MATT5	IB	Specifies table references for temperature-dependent, anisotropic, thermal material properties.
MAX	IB	Eigenvector normalization option - used on EIGR, EIGB and EIGC cards.
MAXIMUM DEFØRMATIØN	IC	Indicates scale for deformed structure plots.
MAXIT	PU	Limits maximum number of iterations in nonlinear heat transfer analysis.
MAXLINES	IC	Maximum printer output line count - default value is 20000.
MCE1	FMS	Multipoint Constraint Eliminator - part 1.
MCE2	FMS	Multipoint Constraint Eliminator - part 2.
MDD	DBM	$[M_{dd}]$ - Mass matrix used in direct formulation of dynamics problems (D-7 thru D-9).
MDEMA	P	Parameter indicating equivalence of MDD and MAA.
MDLCEAD	P	Used in printing rigid format error messages for modal complex eigenvalue analysis (D-10).
MDLFRRD	P	Used in printing rigid format error messages for modal frequency response (D-11).
MDLTRD	P	Used in printing rigid format error messages for modal transient response (D-12).
MEF1	DBT	Modal element forces, Sort 1 for ØFP.
MEF2	DET	Modal element forces, Sort 2 for ØFP.
MERGE	FMM	Matrix merge functional module.
MES1	DBT	Modal element stresses, Sort 1 for ØFP.
MES2	DBT	Modal element stresses, Sort 2 for ØFP.
METHØD	IC	Selects method for real eigenvalue analysis.
METHØD	IS	Identifies EIGR Bulk Data card.
METHØD$	M	Indicates restart with change in eigenvalue extraction procedures.
MFF	DBM	$[M_{ff}]$ - Partition of mass matrix.
MGG	DBM	$[M_{gg}]$ - Mass matrix generated by Structural Matrix Assembler.
MHH	DBM	$[M_{hh}]$ - Mass matrix used in modal formulation of dynamics problems (D-10 thru D-12).
MI	DBM	$[m]$ - Modal mass matrix.
MIND	P	Minimum diagonal term of $[U_{oo}]$.
MKAERØ1	IB	Provides table of Mach numbers and reduced frequencies (k).
MKAERØ2	IB	Provides list of Mach numbers (m) and reduced frequencies (k).

MLL	DBM	$[M_{\ell\ell}]$ - Partition of mass matrix.
MLR	DBM	$[M_{\ell r}]$ - Partition of mass matrix.
MMTX	DBS	Mass matrix.
MNN	DBM	$[M_{nn}]$ - Partition of mass matrix.
MØA	DBM	$(M_{oa}]$ - Partition of mass matrix.
MØDA	FMX	User dummy module.
MØDACC	FMS	Mode Acceleration Output Reduction Module.
MØDACC	PU	A parameter to use the mode acceleration method.
MØDAL	IC	Requests structure plots of mode shapes.
MØDAL	P	Indicates modal as opposed to direct formulation of dynamics.
MØDAL CØMPLEX EIGENVALUES	IA	Selects rigid format for modal complex eigenvalue analysis.
MØDAL FREQUENCY RESPØNSE	IA	Selects rigid format for modal frequency and random response.
MØDAL TRANSIENT RESPØNSE	IA	Selects rigid format for modal transient response.
MØDB	FMX	User dummy module.
MØDC	FMX	User dummy module.
MØDCØM	NP	Defines an array for module communications.
MØDEL	IC	Indicates model number of structure plotter.
MØDES	IA	Selects rigid format for normal mode analysis.
MØDES	IC	Duplicates output requests for eigenvalue problems.
MØDES	IS	Modes output request.
MØDES	P	Used in printing rigid format error messages for normal modes analysis (D-3).
Modified Restart	PH	Restarting (see Restart) a NASTRAN problem and redirecting its solution by changing the rigid format and/or selected input data.
Module	PH	A logical group of subroutines which performs a defined function.
MØMAX	IB	Conical shell moment definition card.
MØMENT	IB	Static moment load definition (vector).
MØMENT1	IB	Static moment load definition (magnitude and two grid points).
MØMENT2	IB	Static moment load definition (magnitude and four grid points).
MØØ	DBM	$[M_{oo}]$ - Partition of mass matrix.
MPC	IB	Multipoint constraint definition.

MPC	IC	Selects set of multipoint constraings for structural displacement or heat transfer boundary temperature relationships.
MPC$	M	Indicates restart with change in multipoint constraints.
MPCADD	IB	Multipoint constraint set definition.
MPCAX	IB	Conical shell multipoint constraint definition.
MPCFØRCES	IC	Requests multipoint forces of constraint at a set of points in Rigid Formats D-1, 2, 3, 14, 15.
MPCF1	P	No multipoint constraints.
MPCF2	P	No change in multipoint constraints for loop.
MPCS	IB	Specifies multipoint constraints for substructuring.
MPHIPA1	DBT	Eigenvectors, PA-set, SØRT1.
MPHIPA2	DBT	Eigenvectors, PA-set, SØRT2.
MPL	PH	Module properties list. The MPL defines each DMAP module's name, the number of input, output and scratch files required and the parameter list. It is used by the preface module XGPI to generate the ØSCAR.
MPT	DBT	Material Properties Table - output by Input File Processor.
MPY	M	Parameter constant used in executive module PARAM.
MPYAD	FMM	Performs multiply-add matrix operation.
MQP1	DBT	Constraint forces, PA-set, SØRT1.
MQP2	DBT	Constraint forces, PA-set, SØRT2.
MR	DBM	$[M_r]$ - Rigid body mass matrix.
MREDUCE	IS	Real modal reduction request.
MRR	DBM	$[M_{rr}]$ - Partition of mass matrix.
MTRXIN	FMS	Selects direct input matrices for current loop in dynamics problems (D-7 thru D-12).
MX	IC	Indicates negative x-axis direction for structure plot.
MXHH	DBM	Total modal mass matrix - h-set.
MY	IC	Indicates negative y-axis direction for structure plot.
MZ	IC	Indicates negative z-axis direction for structure plot.

N	M	Used in parameter section of DMAP statement. Indicates that parameter may not be given an initial value with a PARAM bulk data card.
N	P	Parameter value used by MATGPR to print N-set matrices.
NAME	IS	Specifies Phase 1 basic substructure name or names the resulting substructure in Phase 2.
NASTPLT	IC	Requests NASTRAN general purpose plotter.
NASTRAN	M	Acronym for NAsa STRuctural ANalysis program.
NASTRAN Data Deck	PH	The composite deck consisting of the Executive Control Deck, the Case Control Deck, the Substructure Control Deck, and the Bulk Data Deck. This deck, when preceeded by any necessary operating system control cards, constitutes the complete card input for a NASTRAN run (PM-5).
NCHECK	IC	Requests significant digits to indicate numerical accuracy of element stress and force computations.
NDET	P	Power of 10 used to scale parameter DET.
NE	P	Parameter value used by MATGPR to print out NE-set matrices.
NEIGV	P	Number of real eigenvalues found.
NEVER	P	Set to +1 by a DMAP PARAM statement in the Piecewise Linear Analysis Rigid Format (D-6).
New Problem Tape	PH	See Problem Tape.
NJ	P	Number of degrees of freedom in the j displacement set.
NK	P	Number of degrees of freedom in the k displacement set.
NLFT	DBT	Nonlinear function table.
NLLØAD	IC	Requests nonlinear load output for transient problems.
NLØAD	PU	A parameter of static loading conditions using cyclic symmetry.
NMAX	IS	Identifies number of lowest frequency modes for retained modal coordinates.
NØ	IA	Option used on CHKPNT card, indicates that no checkpoint is desired.
NØA	P	Indicates no constraints applied to structural model.
NØABFL	P	No fluid-structure interface in a hydroelastic problem.
NØB2PP	P	No direct input damping matrix.
NØBGG	P	No viscous damping matrix (D-7 thru D-9).
NØCEAD	P	Used to skip CEAD module when not required.
NØCSTM	P	No Coordinate System Transformation Matrices.
NØD	P	No output request that is limited to independent degrees of freedom.

NØDJE	PU	Positive value selects D1JE and D2JE from INPUTT2.
NØDLT	P	No Dynamic Loads Table.
NØEED	P	No Eigenvalue Extraction Data.
NØELMT	P	No elements are defined.
NØFL	P	No fluid-structure interface and no fluid gravity in a hydroelastic problem.
NØFRL	P	No Frequency Response List.
NØFRY	P	Used by aeroelastic response for transient solution.
NØGENEL	P	No general elements.
NØGPDT	P	No Grid Point Definition Table.
NØGPST	P	No grid point singularity table.
NØGRAV	P	No gravity loads.
NØGUST	P	No gust input.
NØH	L	Used to skip modal output.
NØH	P	Used to skip modal output.
NØK2PP	P	No direct input stiffness matrices.
NØK4GG	P	No structural damping matrix.
NØKBFL	P	No fluid gravity or structural interface in a hydroelastic problem.
NØL	P	No independent degrees of freedom.
NØLIN1	IB	Nonlinear transient dynamic load set definition card.
NØLIN2	IB	Nonlinear transient dynamic load set definition card.
NØLIN3	IB	Nonlinear transient dynamic load set definition card.
NØLIN4	IB	Nonlinear transient dynamic load set definition card.
NØLØØP$	M	Indicates restart of problem without DMAP loop. (PM-4.3.7.1).
NØM2DPP	P	No direct input mass matrix from Bulk Data Deck.
NØM2PP	P	No direct input mass matrices.
NØMGG	P	If functional module SMA2 generates a zero mass matrix, NOMGG is set to -1. Otherwise, it is set to +1.
NØMØD	P	Mode acceleration data recovery not requested.
NØNCUP	P	Indicates diagonal MHH, BHH, and KHH allowing uncoupled solution in TRD and FRRD.
NØNE	IC	Override for output and bulk data deck echo requests.
NØNLIFT	P	No nonlinear function table.

NØNLINEAR	IC	Selects nonlinear load for transient problems.
NØNLINEAR STATIC HEAT TRANSFER ANALYSIS	IA	Selects rigid format for nonlinear static analysis using heat transfer.
NØNLSTR	P	No stress output request for nonlinear elements (D-6).
NØP	M	Parameter constant used in executive module PARAM.
NØP	P	No output request involving dependent degrees of freedom or stresses.
NØPF	L	Skip load calculations in transient aeroelastic response.
NØPSDL	P	No Power Spectral Density List.
NØRMAL MØDES	IA	Selects rigid format for normal mode analysis.
NØRMAL MØDES ANALYSIS WITH CYCLIC SYMMETRY	IA	Selects rigid format for normal modes analysis using cyclic symmetry.
NØRMAL MØDES WITH DIF-FERENTIAL STIFFNESS	IA	Selects rigid format for normal modes analysis with differential stiffness effects.
NØRN	P	No random requests.
NØSET	P	No dependent coordinates.
NØSIMP	P	No structural elements are defined.
NØSØRT2	P	No request for output sorted by point number or element number.
NØSR	P	No single-point constraints or free body supports.
NØT	M	Parameter constant used in utility module PARAM.
NØTFL	P	No Transfer Function List.
NØTRL	P	No Transient Response List.
NØUE	P	No extra points introduced for dynamic analysis.
NØUE1	L	No extra points.
NØXYCBD	P	-1 indicates no XY output requests.
NØXYØUT	L	No XY-output requests.
NØXYPL	P	No XY-plot requests.
NØXYPLTT	L	No XY-plot requests.
NPLALIM	P	Set by module PLA1 as the Piecewise Linear Analysis Rigid Format DMAP loop counter. (D-6)
NPTP	M	New Problem Tape - a reserved NASTRAN physical file which must be set up by the user when used.

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NSEGS	PU	A parameter of identical segments in the structural model using cyclic symmetry.
NSIL	P	Order of SIL table.
NSIL1	P	Number of grid and scalar points.
NSKIP	P	Locate current boundary conditions in Case Control.
NT	PU	A parameter to limit the cumulative number of iterations for the static analysis with differential stiffness loops.
NUMF	IA	Used to add problem deck to NUMF, list it and punch UMF card.
NUMF	M	New User Master File - used only when operating NASTRAN as a user master file editor. (See UMFEDIT). A reserved NASTRAN physical file which must be set up by the user when used.
NVECTS	P	Number of eigenvectors found.

Ø	P	Parameter value used by MATGPR to print Ø-set matrices.
ØBEF1	DBT	Element force output table (D-5).
ØBES1	DBT	Element stress output table (D-5).
ØBQG1	DBT	Forces of single point constraint output table (D-5).
ØCEIGS	DBT	Complex eigenvalue summary table (D-7, D-10).
ØCPHIP	DBT	Complex eigenvector output table (D-7, D-10).
ØCPHIPA	DBT	Complex eigenvector output table, aeroelastic.
ØEF1	DBT	Element force output table (D-1, D-2, D-4, D-5, D-6).
ØEF2	DBT	Element force output table - SØRT2 (D-9, D-12).
ØEFB1	DBT	Element force output table (D-4).
ØEFC1	DBT	Element force output table - complex (D-7, D-8, D-10, D-11).
ØEFC2	DBT	Element force output table - complex - SØRT2 (D-8, D-11).
ØEIGS	DBT	Real Eigenvalue summary output table (D-3, D-5).
ØES1	DBT	Element stress output table (D-1, D-2, D-4, D-5, D-6).
ØES2	DBT	Element stress output table - SØRT2 (D-9, D-12).
ØESB1	DBT	Element stress output table (D-4).
ØESC1	DBT	Element stress output table - complex (D-7, D-8, D-10, D-11).
ØESC2	DBT	Element stress output table - complex - SØRT2 (D-8, D-11).
ØFP	FMS	Output File Processor.
ØFREQ	IC	Output Frequency set.
ØFREQUENCY	IC	Selects a set of frequencies to be used for output requests in frequency response problems (default is all frequencies) or flutter velocities.
ØGPST	DBT	Grid point singularity output table.
ØGPWG	DBT	Grid point weight generator output table.
ØLDBØUND	IS	Flag to identify rerunning problem with previously defined boundary set.
ØLDMØDES	IS	Flag to identify rerunning problem with previously computed modal data.
Old Problem Tape	PH	See Problem Tape.
ØLØAD	IC	Request for output of external load vector.
ØLØAD	IS	Applied load output request.
ØMIT	IB	Omitted coordinate definition card.

ØMIT	P	Indicates no omitted coordinates.
ØMIT1	IB	Omitted coordinate definition card.
ØMITAX	IB	Omitted coordinate definition card for conical shell problems.
ØNLES	DBT	Output table for nonlinear element stresses (D-6).
Open Core	PH	A contiguous block of working storage defined by a labeled common block, whose length is a variable determine by the NASTRAN executive routine CØRSZ.
ØPG1	DBT	Static load output table (D-1, D-2, D-4, D-5, D-6).
ØPHID	DBT	Output table for complex eigenvectors - solution set (D-7).
ØPHIG	DBT	Eigenvector output table (D-3, D-5).
ØPHIH	DBT	Output table for complex eigenvectors - solution set (D-10).
ØPNL1	DBT	Output table for nonlinear loads - solution set, SØRT1 (D-9, D-12).
ØPNL2	DBT	Output table for nonlinear loads - solution set, SØRT2 (D-9, D-12).
ØPP1	DBT	Dynamic load output table (D-9, D-12).
ØPP1	DBT	Aerodynamic transient load output table, sort 1.
ØPP2	DBT	Dynamic load output table - SØRT2 (D-9, D-12).
ØPPC1	DBT	Dynamic load output table - SØRT1, complex (D-8, D-11).
ØPPC2	DBT	Dynamic load output table - SØRT2, complex (D-8, D-11).
ØPT	PU	Controls the type of multipoint constraint output.
ØPTIØNS	IS	Defines matrix types.
ØPTP	M	Old Problem Tape - a reserved NASTRAN physical file which must be set up by the user when used.
ØQBG1	DBT	Forces of single-point constraint output table (D-4).
ØQG1	DBT	Single-point constraint force output table (D-1, D-2, D-4, D-5, D-6).
ØQP1	DBT	Single-point constraint force output table SØRT1 (D-9, D-12).
ØQP2	DBT	Single-point constraint force output table SØRT2 (D-9, D-12).
ØQPC1	DBT	Single-point constraint force output table - complex, SØRT1 (D-7, D-8, D-10, D-11).
ØQPC2	DBT	Single-point constraint force output table - complex, SØRT2 (D-7, D-8, D-10, D-11).
ØQPCA1	DBT	Complex constraint force output table, aeroelastic.
ØR	M	Parameter constant used in executive module PARAM.

ØRIGIN	IC	Locates origin for structure plot.
ØRTHØGRAPHIC	IC	Specifies orthographic projection for structure plot.
ØSCAR	PH	Operation sequence control array. Executive table residing on the Data Pool File which contains the sequence of operations to be executed for a problem solution. The ØSCAR is an expansion of a DMAP sequence, either input by the user or extracted from a rigid format, in internal format.
ØTIME	IC	Selects a set of times to be used for output requests in transient analysis problems (default is all times).
ØUBGV1	DBT	Displacement vector output table (D-4).
ØUDV1	DBT	Displacement vector output table - solution set, SØRT1 (D-9).
ØUDV2	DBT	Displacement vector output table - solution set, SØRT2 (D-9).
ØUDVC1	DBT	Displacement vector output table - solution set, SØRT1, complex (D-8, D-11).
ØUDVC2	DBT	Displacement vector output table - solution set, SØRT2, complex (D-8, D-11).
ØUGV1	DBT	Displacement output table (D-1, D-2, D-4, D-5, D-6).
ØUHV1	DBT	Displacement vector output table - solution set, SØRT1 (D-12).
ØUHV2	DBT	Displacement vector output table - solution set, SØRT2 (D-12).
ØUHVC1	DBT	Displacement vector output table - solution set, SØRT1, complex (D-11).
ØUHVC2	DBT	Displacement vector output table - solution set, SØRT2, complex (D-11).
ØUPV1	DBT	Displacement vector output table - SØRT1 (D-9, D-12).
ØUPV2	DBT	Displacement vector output table - SØRT2 (D-9, D-12).
ØUPVC1	DBT	Displacement vector output table - complex, SØRT1 (D-8, D-11).
ØUPVC2	DBT	Displacement vector output table - complex, SØRT2 (D-8, D-11).
ØUTPUT	FMX	Auxiliary output file processor.
ØUTPUT	IC	Marks beginning of printer output request packet - optional.
ØUTPUT	IS	Specifies optional output results.
Output Data Block	PH	A data block output from a module. A data block may be output from one and only one module. Having been output, it may be used as an input data block as many times as necessary.
ØUTPUT1	FMU	Writes data blocks on GINØ-written user tapes.
ØUTPUT2	FMU	Writes data blocks on FØRTRAN-written user tapes.
ØUTPUT3	FMU	Punches matrices on DMI cards.
ØUTPUT4	FMX	Auxiliary output file processor.

P	P	Parameter value used in MATGPR to print P-set matrices.
P	PH	Flutter analysis method.
Packed format	PH	A matrix is said to be in packed format if only the nonzero elements of the matrix are written.
PAERØ1	IB	Aerodynamic Panel Property.
PAERØ2	IB	Properties of aerodynamic bodies.
PAERØ3	IB	Defines Mach Box geometries.
PAERØ4	IB	Properties of strips (strip theory).
PAERØ5	IB	Properties of strips (piston theory).
PAPER SIZE	IC	Selects paper size for structure plots using table plotters.
PAPP	DBS	Appended load vectors.
PARAM	FMU	Manipulates parameter values.
PARAM	IB	Parameter definition card.
Parameter	PH	A FØRTRAN variable communicated to a DMAP module by the NASTRAN Executive System through blank common. A parameter's position in the DMAP calling sequence to a module corresponds to the position of the parameter in blank common at module execution time.
PARAML	FMU	Selects parameters from a user input matrix or table.
PARAMR	FMU	Performs specified operations on real or complex parameters.
PARTN	FMM	Matrix partitioning functional module.
PARTVEC	FMX	User dummy module.
PASSWØRD	IS	SØF file protection.
PBAR	IB	Bar property definition card.
PBL	DBM	A scalar multiple of the PL load vector. Used only in the Differential Stiffness Rigid Format (D-4).
PBS	DBM	A scalar multiple of the PL load vector. Used only in the Differential Stiffness Rigid Format (D-4).
PCDB	DBT	Plot control data block (table for use with structure plotter functional module PLTSET).
PCØNEAX	IB	Conical shell element property definition card.
PCPHIPA	DBT	Complex displacement plot file.
PDAMP	IB	Scalar damper property definition card.
PDF	DBM	Dynamic load matrix for frequency analysis.
PDT	DBM	Linear dynamic load matrix for transient analysis.

PDUMi	IB	Property definition card for dummy elements 1 through 9.
PELAS	IB	Scalar elastic property definition card.
PEN	IC	Selects pen size for structure plots using table plotters.
PENSIZE	IC	Selects pen size for X-Y plots using table plotters.
PERSPECTIVE	IC	Specifies perspective projection for structure plots.
PFILE	P	Parameter used by PLØT module.
PG	DBM	Incremental load vector used in Piecewise Linear Analysis (D-6).
PG	DBM	Statics load vector generated by SSG1.
PG1	DBM	Static load vector for Piecewise Linear Analysis (D-6).
PGG	DBM	Appended static load vector (D-1, D-2).
PGV1	DBM	Matrix of successive sums of incremental load vectors used only in Piecewise Linear Analysis Rigid Format (D-6).
PHASE	IC	Requests magnitude and phase form of complex quantities.
Phase 1	PH	An operation to create matrices and load vectors for substructuring analysis.
Phase 2	PH	An operation to combine and reduce matrices and load vectors for substructuring analysis.
Phase 3	PH	An operation to recover detailed data reduction for substructuring analysis.
PHBDY	IB	Boundary element property definition card for heat transfer analysis.
PHF	DBM	Total frequency response loads, modal.
PHFI	DBM	Non-gust frequency response loads, modal.
PHIA	DBM	$[\phi_a]$ - Real eigenvectors - solution set.
PHIAH	DBM	Eigenvectors, A-set.
PHID	DBM	$[\phi_a]$ - Complex eigenvectors - solution set, direct formulation.
PHIDH	DBM	$[\phi_{dh}]$ - Transformation matrix between modal and physical coordinates.
PHIG	DBM	$[\phi_g]$ - Real eigenvectors.
PHIH	DBM	$[\phi_h]$ - Complex eigenvectors - solution set, modal formulation.
PHIHL	DBM	Appended complex mode shapes - h-set.
PHIK	DBM	Eigenvectors, aerodynamic box points.
PHIL	DBS	Left side eigenvector matrix from unsymmetric CREDUCE operation.
PHIP	DBM	Eigenvectors, P-set.
PHIPA	DBM	Eigenvectors, PA-set.

PHIPS	DBM	Eigenvectors, PS-set.
PHIS	DBS	Eigenvector matrix.
Physical Points	PH	Grid points and extra scalar points introduced for dynamic analysis.
PIECEWISE LINEAR	IA	Selects rigid format for piecewise linear analysis.
Pivot Point	PH	The first word of each record of the GPCT and ECPT data blocks is called the pivot point.
PJUMP	P	Used to skip deformed plots.
PK	PH	Flutter analysis method.
PKF	DBML	Forces an aerodynamic boxes, as a function of frequency.
PL	DBM	$\{P_\ell\}$ - Partition of load vector.
PLA	P	Used in printing rigid format error messages for Piecewise Linear Analysis (D-6).
PLA1	FMS	Piecewise Linear Analysis - phase 1.
PLA2	FMS	Piecewise Linear Analysis - phase 2.
PLA3	FMS	Piecewise Linear Analysis - phase 3.
PLA4	FMS	Piecewise Linear Analysis - phase 4.
PLACØUNT	P	Loop counter in Piecewise Linear Analysis (D-6).
PLALBL2A	L	Used in the Piecewise Linear Analysis Rigid Format only. (D-6)
PLALBL3	L	Used in the Piecewise Linear Analysis Rigid Format only. (D-6)
PLALBL4	L	Used in the Piecewise Linear Analysis Rigid Format only. (D-6)
PLCØEFFICIENT	IC	Selects the coefficient set for Piecewise Linear Analysis problems.
PLFACT	IB	Piecewise Linear Analysis factor definition card.
PLI	DBM	$\{P_\ell^i\}$ - Partition of inertia relief load vector.
PLIMIT	IB	Property Optimization limits.
PLØAD	IB	Pressure load definition (D-1, D-2, D-4, D-5, D-6).
PLØAD2	IB	Element pressure loading for two-dimensional elements (D-1, D-2, D-4, D-5, D-6).
PLØT	FMS	Structure plot generator.
PLØT	IC	Execution card for structure plotter.
PLØT	IS	Phase 2 undeformed plot request.
PLØT$	M	Indicates restart with a structure plot request.

Plot Tapes	PH	Magnetic tapes containing NASTRAN generated data to drive offline plotters. PLT1 is the name of the BCD plot tape and PLT2 is the name of binary plot tape.
PLØTEL	IB	Plot element definition card used to defind convenient reference lines in structure plots.
PLØTTER	IC	Used to select one of several available plotters for structure plotter.
PLØTX1	DBT	Messages from plot module concerning action taken by the structure plotter in processing undeformed structure plots.
PLØTX2	DBT	Messages from plot module concerning action taken by the structure plotter in processing deformed structure plots.
PLØTX3	DBT	Deformed plot messages for aeroelastic.
PLSETNØ	P	Set number on a PLFACT bulk data card chosen by the user in his case control deck. Used only in Piecewise Linear Analysis (D-6).
PLT1	M	A reserved NASTRAN physical file which must be set up by the user when used - see Plot Tapes.
PLT2	M	A reservec NASTRAN physical file which must be set up by the user when used - see Plot Tapes.
PLTFLG	P	Parameter used by PLØT module.
PLTMRG	FMSS	Substructure plot set data merge.
PLTPAR	DBT	Plot control table.
PLTPARA	DBT	Plot control table PLTPAR, with aeroelastic data.
PLTS	DBS	Plot sets and other data required for Phase 2 plotting.
PLTSET	FMS	Plot set definition processor.
PLTSETA	DBT	Set definitions for aerodynamic plots.
PLTSETX	DBT	Error messages for plot sets.
PLTTRAN	FMS	Prepares data blocks for acoustic analysis plots.
PLTTRAN	FMS	Transforms grid point definition tables for scalar points into a format for plotting.
PMASS	IB	Scalar mass property definition card.
PNLD	DBM	$\{P_d^n\}$ - Nonlinear loads in direct transient problem.
PHLH	DBM	$\{P_h^n\}$ - Nonlinear loads in modal transient problem.
PØ	DBM	$\{P_o\}$ - Partition of load vector.
PØAP	DBS	Appended load vectors on omitted points.
PØI	DBM	$\{P_o^i\}$ - Partition of inertia relief load vector.
PØINT	IB	Eivenvalue analysis normalization option for eigenvectors - see EIGR, EIGC, EIGB cards.

PØINTAX	IB	Axisymmetric Point.
PØØL	M	Pool file used by file allocator.
PØSITIØN	IS	Specifies initial position of input file.
PØUT$	M	Indicates restart with a printer output request.
PØVE	DBS	Load vectors on points omitted during matrix reduction.
PPF	DBM	Dynamic loads for frequency response.
PPHIG	DBM	Eigenvector components used to plot deformed shape. (D-3, D-5).
PPT	DBM	Linear dynamic loads for transient analysis.
PQDMEM	IB	Quadrilateral membrane element property definition card.
PQDMEM1	IB	Isoparametric quadrilateral membrane element property definition card.
PQDMEM2	IB	Quadrilateral membrane element property definition card.
PQDPLT	IB	Quadrilateral bending element property definition card.
PQUAD1	IB	General quadrilateral element property definition card.
PQUAD2	IB	Homogeneous quadrilateral element property definition card.
PREC	P	Precision of computer IBM = 2 UNIVAC = 2 CDC = 1
PRECHK	EM	Predefined automated checkpoint.
Preface	PH	Executive routines which are executed prior to the execution of the first module in a DMAP sequence. The Preface consists of the executive routines necessary to generate initial NASTRAN operational data and tables. The primary Preface routines are GNFIAT, XCSA, IFP1, XSØRT, IFP, IFP3, and XGPI.
PREFIX	IS	Prefix to rename equivalenced lower level substructures.
PRESAX	IB	Defines static pressure loading for the conical shell element.
PRESPT	IB	Defines a point in a hydroelastic model for output purposes.
PRESSURE	IC	Request for output of pressure and displacement vector or eigenvector for a hydroelastic problem.
PRINT	IA	Used to list all problem decks from UMF and Summary Table of Contents.
PRINT	IS	Stores modal or solution data and prints data requested.
PRINT	PU	Controls printing of flutter summary.
Problem Tape	PH	A magnetic tape containing data necessary for NASTRAN problem restarts. A tape being generated is designated as the New Problem Tape (NPTP) and its content is largely controlled by the DMAP instruction CHKPNT. This same tape when used as input to a subsequent NASTRAN restart is designated as the Old Problem Tape (ØPTP).

PRØD	IB	Rod property definition card.
PRØJECTIØN PLANE SEPARATIØN	IC	Separation of observer and projection plane for structure plots.
PRTMSG	FMS	Message generator.
PRTPARM	FMU	Prints DMAP diagnostic messages and parameter values.
PS	DBM	$\{P_s\}$ - Partition of static load vector.
PSDF	DBM	Power Spectral Density Function table.
PSDF	IC	Request for output of Power Spectral Density Function in Random Analysis (D-9, D-11).
PSDL	DBT	Power Spectral Density List.
Pseudo Modified Restart	PH	Restarting (see Restart) a NASTRAN problem and redirecting its solution but only affecting output data.
PSF	DBM	Partition of load vector for transient analysis.
PSHEAR	IB	Shear panel property definition card.
PST	DBM	Partition of linear load vector for transient analysis.
PTITLE	IC	Structure plot frame title.
PTØRDRG	IB	Toroidal ring property definition card.
PRTBSC	IB	Basic bending triangular element property definition card.
PTRIA1	IB	General triangular element property definition card.
PTRIA2	IB	Homogeneous triangular element property definition card.
PTRIM6	IB	Linear strain triangular membrane property.
PTRMEM	IB	Triangular membrane element property definition card.
PTRPLT	IB	Triangular bending element property definition card.
PTRPLT1	IB	Triangular plate property.
PTRSHL	IB	Higher order triangular shell element property.
PTUBE	IB	Tube property definition card.
PTWIST	IB	Twist panel property definition card.
PUBGV1	DBT	Displacement vector components used to plot deformed shape (D-4, D-5).
PUGV	DBT	Displacement vector components used to plot deformed shape (D-1, D-2).
PUGV1	DBT	Displacement components used to plot deformed shape (D-6).
PUNCH	IA	Used to punch the problem deck from UMF or copy the problem deck from UMF onto NUMF and punch it.

PUNCH	IC	Output media request (PRINT or PUNCH)
PUNPRT	IA	Used to punch and print the problem deck from UMF or copy the problem deck from UNF onto NUMF and punch and print it.
PURGE	EM	DMAP statement which causes conditional purging of data blocks.
Purge	PH	A data block is said to be purged when it is flagged in the FIAT so that it will not be allocated to a physical file and so that modules attempting to access it will be signaled.
PUVPAT	DBT	Displacement vector used for plots, PA-set for aeroelastic
PVEC	DBS	Load vectors.
PVISC	IB	Viscous element property definition card.
PVT	PH	Parameter value table. The PVT contains BCD names and values of all parameters input by means of PARAM bulk data cards. It is generated by the preface module IFP and is written on the Problem Tape.
P1	PU	INPUTT2 rewind option.
P2	PU	INPUTT2 unit number.
P3	PU	INPUTT2 tape id.

Q	PU	Parameter which defines the dynamic pressure.
QBDY1	IB	Defines uniform heat flux into HBDY elements.
QBDY2	IB	Defines grid point heat flux into HBDY elements.
QBG	DBM	Single point forces of constraint in the Differential Stiffness Rigid Format (D-4).
QDMEM	IC	Requests structure plot for all QDMEM elements.
QDMEM1	IC	Requests structure plot for all QDMEM1 elements.
QDMEM2	IC	Requests structure plot for all QDMEM2 elements.
QDPLT	IC	Requests structure plot for all QDPLT elements.
QG	DBM	Constraint forces for all grid points.
QHBDY	IB	Defines thermal load for steady-state heat conduction.
QHHL	DBML	Aerodynamic matrix list - h-set.
QHJL	DBML	Aerodynamic matrix for gust calculations.
QJHL	DBML	Aerodynamic transformation matrix between h and j sets.
QKHL	DBML	Aerodynamic matrix for aerodynamic force data recovery.
QP	DBM	Constraint forces for all physical points.
QPA	DBM	Constraint forces, PA-set.
QPAC	DBM	Constraint forces, complex, PA-set.
QPC	DBM	Complex single point forces of constraint for all physical points.
QPP2	DBT	Aerodynamic transient load output, sort 2.
QR	DBM	$\{q_r\}$ - Determinant support forces.
QS	DBM	$\{q_s\}$ - Single-point constraint forces.
QUAD1	IC	Requests structure plot for all QUAD1 elements.
QUAD2	IC	Requests structure plot for all QUAD2 elements.
QVEC	DBS	Reaction force vectors.
QVECT	IB	Defines thermal vector flux from distant source.
QVØL	IB	Defines volume heat generation.

R	P	Parameter value used by MATGPR to print R-set matrices.
R1	IC	Request for X-Y plot of the first rotational component (UM-4.2).
R1IP	IC	Request for X-Y plot of the first rotational component - imaginary and phase angle (UM-4.2).
R1RM	IC	Request for X-Y plot of the first rotational component - real and magnitude (UM-4.2).
R2	IC	Request for X-Y plot of the second rotational component (UM-4.2).
R2IP	IC	Request for X-Y plot of the second rotational component - imaginary and phase angle (UM-4.2).
R2RM	IC	Request for X-Y plot of the second rotational component - real and magnitude (UM-4.2).
R3	IC	Request for X-Y plot of the third rotational component (UM-4.2).
R3IP	IC	Request for X-Y plot of the third rotational component - imaginary and phase angle (UM-4.2).
R3RM	IC	Request for X-Y plot of the third rotational component - real and magnitude (UM-4.2).
RADLIN	P	Controls linearization of radiation effects in transient heat transfer analysis.
RADLST	IB	List of radiation areas.
RADMTX	IB	Radiation exchange coefficients.
RANDØM	IC	Selects the RANDPS and RANDT cards to be used in random analysis.
RANDØM	FMS	Random response solution generator.
RANDPS	IB	Power spectral density specification.
RANDT1	IB	Autocorrelation function time lag.
RANDT2	IB	Autocorrelation function time lag.
RANGE	IS	Identifies frequency range for real or complex retained modal coordinates.
RBMG1	FMS	Rigid body matrix generator - part 1.
RBMG2	FMS	Rigid body matrix generator - part 2.
RBMG3	FMS	Rigid body matrix generator - part 3.
RBMG4	FMS	Rigid body matrix generator - part 4.
RCØVR	FMSS	Recover Phase 2 substructure results.
RCØVR3	FMSS	Recover substructure results for Phase 3.
REACT	P	Flag for rigid body mode calculations.

READ	FMS	Real Eigenvalue Analysis - Displacement.
REAL	IC	Requests real and imaginary form of complex quantities.
REAL EIGENVALUES	IA	Selects rigid format for normal mode analysis.
RECØVER	IS	Phase 2 solution data recovery or Phase 1, 2 modal reduction request.
REDUCE	FMSS	Reduction of substructure degrees of freedom.
REDUCE	IS	Phase 2 reduction to retained degrees of freedom request.
REEL	IA	Term appearing on the checkpoint dictionary cards indicating the physical reel on which a data block appears.
Reentry Point	PH	The point in the DMAP sequence at which a problem terminated and hence the point at which it can be restarted (see Restart).
REGIØN	IC	Specifies portion of frame to be used for structure plot.
REIG	P	Parameter used in SDR2 to indicate Normal Mode Analysis (D-3).
RELES	IB	Specifies grid point degrees of freedom to be disconnected - overrides CØNCT and automatic connectivities using substructuring.
REMØVE	IA	Used to copy problem decks from UMF onto NUMF up to pid and skip over problem pid.
REPCASE	IC	Allows another output request for the previous subcase (D-1, D-2).
REPEAT	P	Controls looping in Static Analysis (D-1, D-2).
REPEATD	P	Controls looping in Static Analysis with Differential Stiffness (D-4).
REPEATE	P	Controls looping in Complex Eigenvalue Analysis (D-7, D-10).
REPEATF	P	Controls looping in Frequency Response Analysis (D-8, D-11).
REPEATT	P	Controls looping in Transient Response Analysis (D-9, D-12).
REPT	EM	DMAP statement to conditionally repeat a loop.
RESPØNSE	IC	Request for X-Y plot of any response outputs from transient or frequency response analysis (D-8, D-9, D-11, D-12).
RESTART	IA	First control card of checkpoint dictionary. Contains identification of checkpoint tape.
Restart	PH	Initiating a NASTRAN problem solution at a place other than its logical beginning by utilizing an Old Problem Tape created during a previous run.
RESTØRE	IS	Reloads the SØF from an external file.
RFØRCE	IB	Rotational force definition card.
RFØRCE$	M	Indicates restart with change in rotational force.
RG	DBM	Multipoint constraint equations.

RGRID	IS	Specifies grid point in the basic substructure to define reference point for inertia relief shapes. Defaults to origin of basic substructure coordinate system.
RIGHT TICS	IC	Request for tic marks to be plotter on right hand edge of frame for X-Y plots.
Rigid Format	PH	A fixed prestored DMAP sequence and its associated restart tables which perform a specific problem solution.
Rigid Format Switch	PH	A type of restart (see Restart) in which the problem is changed from one Rigid Format to another.
RINGAX	IB	Conical shell ring definition card.
RINGFL	IB	Hydroelastic axisymmetric point definition card.
RLØAD1	IB	Frequency response load set definition.
RLØAD2	IB	Frequency response load set definition.
RMG	FMH	Radiation matrix generator - generates $[R_{gg}]$.
RNAME	IS	Specifies basic substructure to define reference point for inertia.
RØD	IC	Requests structure plot for all RØD elements.
RP	DBM	Partitioning vector set D to A and E.
RSAVE	IS	Save REDUCE decomposition product or indicates the decomposition product of the interior point stiffness.
RUBLV	DBM	Residual vector - Differential Stiffness Rigid Format (D-4).
RULV	DBM	Residual vector for independent degrees of freedom.
RUN	IS	Specifies run options.
RUØV	dbm	residual vector for omitted degrees of freedom.
RXY	IC	Requests vector sum of X and Y deformation components for structure plot.
RXYZ	IC	Requests vector sum of X, Y and Z deformation components for structure plot.
RXZ	IC	Requests vector sum of X and Z deformation components for structure plot.
RYX	IC	Requests vector sum of Y and Z deformation components for structure plot.

S	P	Parameter value used by MATGPR to print S-set matrices.
SACCE	IC	Abbreviated form of SACCELERATIØN.
SACCELERATIØN	IC	Output request for solution set acceleration vector. (UM-2.3, 4.2)
SAVE	EM	DMAP statement which causes current value of parameter to be saved.
SAVE	IS	Stores modal or solution data on SØF.
SAVE	M	Save data block for possible looping in DMAP sequence (see FILE).
SAVEPLØT	IS	Requests plot data be saved in Phase 1.
SC	IC	Selects SC 4020 plotter.
SCALAR	FMU	Convert matrix element to parameter.
Scalar Point	PH	A point which is defined on an SPØINT, CELAS1, CELAS2, CELAS3, CELAS4, CMASS1, CMASS2, CMASS3, CMASS4, CDAMP1, CDAMP2, CDAMP3, or CDAMP4 bulk data card. A scalar point has no geometrical coordinates and defines only one degree of freedom of the model.
SCALE	IC	Selects scale for structure plot.
SCE1	FMS	Single-point Constraint Eliminator.
SDAMP	IC	Modal structural damping table selection.
SDAMP4	M	Indicates restart with change in modal damping.
SDAMPING	IC	Selects table which defines damping as a function of frequency in modal formulation problems.
SDISP	IC	Abbreviated form of SDISPLACEMENT.
SDISPLACEMENT	IC	Output request for solution set displacement vector. (UM-2.3, 4.2)
SDR1	FMS	Stress Data Recovery - part 1.
SDR2	FMS	Stress Data Recovery - part 2.
SDR3	FMS	Stress Data Recovery - part 3.
SDRHT	FMH	Heat flux data recovery.
SEARCH	IS	Limits search for automatic connects.
SECTAX	IB	Defines conical shell sector for data recovery.
SEEMAT	FMU	Prints pictorial representation of matrix showing location of nonzero elements.
SEM1	M	The NASTRAN Preface.
SEQEP	IB	Extra point resequencing.
SEQGP	IB	Grid or scalar point resequencing.

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SET	IC	Definition of a set of elements, grid and/or scalar and/or extra points, frequencies, or times to be used in selecting output.
SET1	IB	Defines a set of structural grid points by a list.
SET2	IB	Defines a set of structural grid points by aerodynamic macro elements.
SETVAL	FMU	Parameter value initiator.
SGEN	FMSS	Substructure table generator.
SHEAR	IC	Requests structure plot for all shear panel elements.
SIGMA	PU	Defines Stefan-Boltzmann constant in heat transfer analysis.
SIL	DBT	Scalar Index List for all grid points and extra scalar points introduced for dynamic analysis.
SILGA	DBT	Scalar Index List - Aerodynamic boxes only.
SINCØN	PU	Controls the automatic stiffness matrix singularity removal.
SINE	IC	Conical shell request for sine set boundary conditions.
SING	P	-1 if $[K_{oo}]$ is singular.
SINGLE	P	No single-point constraints.
SKIP BETWEEN FRAMES	IC	Request to insert blank frames on SC 4020 plotter for X-Y plots.
SKJ	DBM	Integration matrix.
SKPMGG	P	Parameter used in statics to control execution of functional module SMA2.
SKPPLT	L	Used to skip plot.
SLBDY	IB	Defines list of points on interface between axisymmetric fluid and radial slots.
SLØAD	IB	Scalar point load definition.
SLT	DBT	Static Loads Table.
SMA1	FMS	Structural Matrix Assembler - phase 1 - generates stiffness matrix $[K_{gg}]$ and structural damping matrix $[K^4_{gg}]$.
SMA2	FMS	Structural Matrix Assembler - phase 2 - generates mass matrix $[M_{gg}]$ and viscous damping matrix $[B_{gg}]$.
SMA3	FMS	Structural Matrix Assembler - phase 3 - add general element contributions to the stiffness matrix $[K_{gg}]$.
SMP1	FMS	Structural Matrix Partitioner - part 1.
SMP2	FMS	Structural Matrix Partitioner - part 2.
SMPYAD	FMM	Performs multiply-add matrix operation for up to five multiplications and one addition.

SØF	IS	Assigns physical files for storage of the SØF.
SØFI	FMSS	SØF into GINØ matrix copier.
SØFIN	IS	Copies substructure items from an external file to the SØF.
SØFØ	FMSS	SØF out from GINØ matrix copier.
SØFØUT	IS	Copies substructure items from the SØF to an external file.
SØFPRINT	IS	Prints selected contents of the SØF.
SØFUT	FMSS	SØF utility module.
SØL	IA	Specifies which rigid format solution is to be used when APP is DISPLACEMENT.
SØLN	DBS	Load factor data or eigenvalues used in a solution.
Solution Points	PH	Points used in the formulation of the general K system.
SØLVE	FMM	Solves a set of linear algebraic equations.
SØLVE	IS	Requests substructure solution.
SØRT	IS	Output sort order.
SØRT1	IC	Output is sorted by frequency or time and then by external ID.
SØRT2	IC	Output is sorted by external ID and then by frequency or time.
SØRT3	M	Output is sorted by individual item or component and then by frequency or time.
SPC	IB	Single-point constraint and enforced deformation definition.
SPC	IC	Selects set of single-point constraints for structural displacements or heat transfer boundary temperatures.
SPC$	M	Indicates restart with change in single-point constraint set selection.
SPC1	IB	Single-point constraint definition.
SPCADD	IB	Single-point constraint set combination definition.
SPCAX	IB	Conical shell single-point constraint definition.
SPCF	IC	Abbreviated form of SPCFØRCE.
SPCF	IS	Reaction force output request.
SPCFØRCE	IC	Requests the single-point forces of constraint at a set of points or the thermal power transmitted to a selected set of points in heat transfer.
SPCS	IB	Specifies single point constraints for substructuring.
SPCS1	IB	Alternate specification of single point constraints for substructuring.
SPCSD	IB	Specifies enforced displacements for single point constraints for substructuring.

Spill	PH	Secondary storage devices are used because there is insufficient main storage to perform a matrix calculation or a data processing operation.
SPLINE	DBT	Splining Data Table.
SPLINE1	IB	Defines surface spline.
SPLINE2	IB	Defines beam spline.
SPLINE3	IB	User data to interpolate deflections at aerodynamic degrees of freedom.
SPØINT	IB	Scalar point definition card.
SSG1	FMS	Static Solution Generator - part 1.
SSG2	FMS	Static Solution Generator - part 2.
SSG3	FMS	Static Solution Generator - part 3.
SSG4	FMS	Static Solution Generator - part 4.
SSGHT	FMH	Solution generator for nonlinear heat transfer analysis.
STATIC	IC	Requests deformed structure plot for problem in Static Analysis.
STATIC ANALYSIS WITH CYCLIC SYMMETRY	IA	Selects rigid format for static analysis using cyclic symmetry.
STATIC HEAT TRANSFER ANALYSIS	IA	Selects rigid format for linear static analysis using heat transfer.
STATICS	IA	Selects statics rigid format for heat transfer or structural analysis.
STATICS	P	Parameter used in SDR2 to indicate Static Analysis.
STEADY STATE	IA	Selects rigid format for nonlinear static heat transfer analysis.
STEPS	IS	Frequency or time step output request for substructuring.
STEREØSCØPIC	IC	Requests stereoscopic projections for structure plot.
STRESS	IC	Requests the stresses in a set of structural elements or the velocity components in a fluid element in acoustic cavity analysis.
Structural Element	PH	One of the finite elements used to represent a part of a structure.
STST	NP	Defines the singularity tolerance in EMG.
SUBCASE	IC	Subcase definition.
SUBCASES	IS	Subcase output request.
SUBCØM	IC	This subcase is a linear combination of previous subcases.
SUBPH1	FMSS	Substructure, Plase 1.

SUBSEQ	IC	Specifies coefficients for SUBCØM subcases.
SUBSTRUCTURE	IS	Initiates the substructure control deck.
Substructure Control Deck	PH	One of the data decks required to run automated multi-stage substructuring. The deck begins with the SUBSTRUCTURE card and terminates with the ENDSUBS card. Cards in this deck cause the necessary alters to the Rigid Format DMAP.
SUBTITLE	IC	Output labeling data for printer output.
SUPAX	IB	Ficticious support for conical shell problem.
SUPØRT	IB	Ficticious support definition card.
SVECTØR	IC	Request for output of eigenvectors in the solution set (D-7, D-10) (UM-2.3, 4.2).
SVELØ	IC	Abbreviated form of SVELØCITY.
SVELØCITY	IC	Requests velocity output for solution set. (UM-2.3, 4.2)
SWITCH	FMU	Interchange two data block names.
SYM	IC	Symmetry subcase delimiter card.
SYMBØLS	IC	Requests symbols at grid points on structure plot.
SYMCØM	IC	Assembly of symmetry subcase delimiter card.
SYMSEQ	IC	Assembly value of symmetry combination card.
SYMTRANSFØRM	IS	Specifies symmetry transformation.

T1	IC	Request for X-Y plot of the first translational component (UM-4.2).
T1IP	IC	Request for X-Y plot of the first translational component - imaginary and phase angle (UM-4.2).
T1RM	IC	Request for X-Y plot of the first translational component - real and magnitude (UM-4.2).
T2	IC	Request for X-Y plot of the second translational component (UM-4.2).
T2IP	IC	Request for X-Y plot of the second translational component - imaginary and phase angle (UM-4.2).
T2RM	IC	Request for X-Y plot of the second translational component - real and magnitude (UM-4.2).
T3	IC	Request for X-Y plot of the third translational component (UM-4.2).
T3IP	IC	Request for X-Y plot of the third translational component - imaginary and phase angle (UM-4.2).
T3RM	IC	Request for X-Y plot of the third translational component - real and magnitude (UM-4.2).
TA1	FMS	Table Assembler.
TABDMP1	IB	Tabular structural damping function for modal formulation (D-10, D-11, D-12).
Table Data Block	PH	A data block which is in tabular form rather than matrix form.
TABLED1	IB	Dynamic load tabular function (D-8, D-9, D-11, D-12).
TABLED2	IB	Dynamic load tabular function (D-8, D-9, D-11, D-12).
TABLED3	IB	Dynamic load tabular function (D-8, D-9, D-11, D-12).
TABLED4	IB	Dynamic load tabular function (D-8, D-9, D-11, D-12).
TABLEM1	IB	Material property tabular function.
TABLEM2	IB	Material property tabular function.
TABLEM3	IB	Material property tabular function.
TABLEM4	IB	Material property tabular function.
TABLES1	IB	Stress-dependent material tabular function for use in Piecewise Linear Analysis (D-6).
TABPCH	FMU	Punches selected tables on DTI bulk data cards.
TABPRT	FMU	Formats selected table data blocks for printing.
TABPT	FMU	Table printer.
TABRNDG	IB	Table of Power Spectral Density for certain gusts.
TABRND1	IB	Tabular function for use in Random Analysis (D-8, D-11).
TABRND2	IB	Tabular function for use in Random Analysis (D-8, D-11).

TABRND3	IB	Tabular function for use in Random Analysis (D-8, D-11).
TABRND4	IB	Tabular function for use in Random Analysis (D-8, D-11).
TABS	P	Defines absolute reference temperature in heat transfer analysis.
TALL EDGE TICS	IC	Request for plotting all edge tic marks on upper half frame for X-Y plots.
TAPE	M	Write data block on physical tape (see FILE).
TCURVE	IC	Curve title for X-Y plot.
TEMP	IB	Grid temperature definition card.
TEMPAX	IB	Temperature definition for conical shell problem.
TEMPD	IB	Grid default temperature definition card.
TEMPERATURE	IC	Selects thermal field for determining both equivalent static loads and material properties.
TEMPLD$	M	Indicates restart with change in thermal set for static loading.
TEMPMT$	M	Indicates restart with change in thermal set for material properties.
TEMPMX$	M	Indicates restart with change in thermal field with thermally dependent material properties.
TEMP(LØAD)	IC	Selects thermal field to be used for determining equivalent static loads.
TEMP(MAT)	IC	Selects thermal field to be used for determining structural material properties or an estimate of the temperature distribution for heat transfer iterations.
TEMPP1	IB	Plate element temperature definition card.
TEMPP2	IB	Plate element temperature definition card.
TEMPP3	IB	Plate element temperature definition card.
TEMPRB	IB	One-dimensional element temperature definition.
TF	IB	Dynamic transfer function definition.
TF$	M	Indicates restart with change in transfer function set selection.
TFL	IC	Transfer function set selection.
TFPØØL	DBT	Transfer function pool.
THERMAL	IC	Request for output of temperature vector in thermal analysis (UM-2.3).
THRU	IC	Forms strings of values within set declarations.
TIC	IB	Transient Initial Condition set definition card.

TIME	IA	User time estimate for problem. This card if required in Executive Control Deck. Integer time value is in minutes.
TIMETEST	FMU	Provides NASTRAN system timing data.
TITLE	IC	Output labeling data for printer output.
TLEFT TICS	IC	Request for tic marks to be plotted on left hand edge of top half frame for X-Y plot.
TLØAD1	IB	Transient load set definition card.
TLØAD2	IB	Transient load set definition card.
TØC	IA	Used to list all problem decks (Summary Table of Contents) by UMF number from UMF.
TØL	DBT	Time output list.
TØL1	DBT	Reduced time output list, uses ØTIME.
TØLERANCE	IS	Limits distance between automatically connected grids.
TRACKS	NP	Defines the format for the number of tracks required for plot data.
Trailer	PH	A six word control block associated with a data block.
TRANRESP	P	Parameter used in SDR2 to indicate Transient Response Analysis (D-9, D-12).
TRANS	IB	Specifies coordinate systems for substructure and grid point transformation.
TRANSFØRM	IS	Defines transformations for named component substructures.
TRANSIENT	IA	Selects rigid format for transient heat transfer analysis.
TRANSIENT HEAT TRANSFER ANALYSIS	IA	Selects rigid format for linear transient analysis using heat transfer.
TRBSC	IC	Requests structure plot for all basic bending triangle elements.
TRD	FMS	Transient Response - Displacement.
TRHT	FMH	Integrates dynamic equation for heat transfer analysis.
TRIA1	IC	Requests structure plot for all TRIA1 elements.
TRIA2	IC	Requests structure plot for all TRIA2 elements.
TRIGHT TICS	IC	Request for tic marks to be plotted on right hand edge of top half frame for X-Y plots.
TRL	DBT	Transient Response List.
TRLG	FMH	Generates dynamic heat flux loads.
TRMEM	IC	Requests structure plot for all triangular membrane elements.
TRNSP	FMM	Transpose functional module.

TRPLT	IC	Request structure plot for all TRPLT elements.
TSTART	P	CPU time at start of flutter loop.
TSTEP	IB	Transient time steps for integration and output.
TSTEP	IC	Transient time step set selection.
TSTEP$	M	Indicates restart with change in transient time step set selection.
TUBE	IC	Requests structure plot for all TUBE elements.
TWIST	IC	Requests structure plot for all TWIST elements.
TYPE	IC	Indicates paper type for structure plots.

UBGV	DBM	Displacement vector for all grid points (D-4).
UBLL	DBM	$[U^b_{\ell\ell}]$ - Upper triangular factor of $[K^b_{\ell\ell}]$.
UBLV	DBM	Displacement solution vector (D-4).
UBØØV	DBM	Scalar multiple of UØØV in Differential Stiffness Rigid Format (D-4).
UDET	IB	Selects unsymmetric decomposition option for determinant method of real eigenvalue analysis.
UDV1T	DBM	Displacement, velocity and acceleration solution vectors in a transient analysis problem - SØRT1. (D-9)
UDV2T	DBM	Displacement, velocity and acceleration solution vectors in a transient analysis problem - SØRT2 (D-9).
UDVF	DBM	Displacement solution vector in a frequency response problem (D-8).
UDVT	DBM	Displacement, velocity and acceleration solution vectors in a transient analysis problem (D-9).
UEVF	DBM	Displacement vector for extra points in a frequency response problem (D-11).
UEVT	DBM	Displacement vector for extra points in a transient response problem (D-12).
UGV	DBM	Displacement vector for all grid points (D-1, D-2, D-4, D-5).
UGV1	DBM	Successive sums of incremental displacement vectors. Piecewise Linear Analysis Rigid Format only (D-6).
UHVF	DBM	Modal frequency response solution vectors (D-11).
UHVT	DBM	Modal transient response solution vectors (D-12).
UHVT1	DBM	Modal amplitudes for aeroelastic transient.
UIMPRØVE	IS	Improved displacement request.
UINV	IB	Selects unsymmetric decomposition option for inverse power method of eigenvalue analysis.
ULL	dbm	$[U_{\ell\ell}]$ - Upper triangular factor of $[K_{\ell\ell}]$.
ULV	DBM	Displacement solution vector in static analyses (D-1, D-2, D-4, D-5).
UMERGE	FMM	Functional module to merge column matrices based on U-set.
UMF	IA	Used to copy UMF problem deck onto NUMF, list it and punch UMF card.
UMF	M	User Master File, a reserved NASTRAN physical file which must be set up by the user when used.
UMFEDIT	IA	Requests User Masetr File operational mode of NASTRAN.
Unmodified Restart	PH	Restarting (see Restart) a problem without changing any data, other than output requests, of the previous run.

Unpool	PH	Remove data block from Pool Tape and place on a file for use by a functional module.
UNSØRT	IC	Requests unsorted echo of Bulk Data Deck (ECHØ=UNSØRT).
UØØ	DBM	$[U_{oo}]$ - Upper triangular factor of $[K_{oo}]$.
UØØV	DBM	Partition of displacement solution vector.
UPARTN	FMM	Functional module to partition matrices based on U-set.
UPPER TICS	IC	Request for tic marks to be plotted on upper edge of frame for X-Y plot.
UPRT	DBS	Partitioning vector used in matrix reduction.
UPV	DBM	Transient solution vectors for all physical points.
UPVC	DBM	Frequency response solution vectors for all physical points.
USERMØDES	is	Flag to indicate modal data have been input on bulk data.
USET	DBT	Displacement set definitions. (PM-1.7.3)
USETA	DBT	Displacement set definitions table - Aerodynamics.
USETD	DBT	Displacement set definitions including extra scalar points.
UVEC	DBS	Displacement vectors or eigenvectors.
UVT1	DBM	Displacements for aeroelastic transient.

V	DBM	Partitioning vector for set F to Ø and A.
V	M	Used in parameter section of DMAP statement. Indicates that parameter is variable and may be changed by module. If changed value is to be used in subsequent DMAP instruction, it must be saved (see SAVE).
VANTAGE PØINT	IC	Location of observer for structure plot.
VDR	FMS	Vector Data Recovery.
VDR	L	Used to skip to VDR module in flutter analysis.
VEC	FMU	Creates partitioning vector based on USET.
VECTØR	IC	Request for output of eigenvectors from real or complex eigenvalue analysis (D-3, D-5, D-7, D-10).
VECTØR	IC	Requests displacements for a selected set of PHYSICAL points.
VELØ	IC	Abbreviated form of VELØCITY.
VELØ	IS	Velocity output request.
VELØCITY	IC	Output request statement for velocity vector. (UM-2.3, 4.2).
VFS	DBM	Partitioning vector for heat transfer analysis.
VIEW	IC	Rotation of object for structure plot.
VISC	IC	Request structure plot for all viscous damper element.
VPS	M	See XVPS.
VREF	PU	Velocity division factor.

W3	PU	Pivotal frequency for uniform structure damping in the direct formulation of transient response problems (D-9).
W4	PU	Pivotal frequency for element structural damping in the direct formulation of transient response problems (D-9).
WTMASS	PU	Weight to mass conversion factor used in SMA2 and GPWG. Default value is 1.0.

X	IC	Requests X vector for deformed structure plot.
XAXIS	IC	Request for drawing of X-axis for X-Y plot.
XBAXIS	IC	Request for drawing of X-axis on bottom half frame for X-Y plot.
XBGRID LINES	IC	Request for drawing grid lines for X-axis on bottom half frame for X-Y plot.
XCSA	EM	Executive Control Section Analysis. The preface module which processes the Executive Control Deck and prepares the control file on the New Problem Tape.
XDIVISIØNS	IC	Request for division marking on X-axis.
XDMAP	EM	Controls the DMAP compiler options.
XGPI	EM	Executive General Problem Initialization. The preface module whose principal function is to generate the ØSCAR. If the problem is a restart, XGPI initializes data blocks and named common blocks for proper restart.
XGRID LINES	EC	Request for grid lines to be drawn on X-axis for X-Y plots.
XINTERCEPT	IC	Specifies intercept of Y-axis on X-axis.
XLØG	IC	Request for logarithmic scales in X-direction.
XMAX	IC	Do not plot points whose X value lies above this value.
XMIN	IC	Do not plot points whose X value lies below this value.
XPAPER	IC	Specifies length of paper in X-direction for table plotter.
XQHHL	P	Appended QHHL data parameter.
XSFA	EM	Executive Segment File Allocator - the administrative manager of data blocks for NASTRAN.
XSØRT	EM	Executive sort routine - the preface module which reads and sorts the Bulk Data Deck and writes the sorted Bulk Data Deck on the New Problem Tape.
XTAXIS	IC	Request for drawing of X-axis on top half frame.
XTGRID LINES	IC	Request for drawing of grid lines on top half frame.
XTITLE	IC	X-axis title for X-Y plots.
XVALUE PRINT SKIP	IC	Request to suppress labeling tic marks over the specified interval.
XVPS	M	Variable Parameter Set Table. Executive table needed for restart. (PM-2.4)
XY	IC	Requests X and Y vectors for deformed structure plot.
XYCDB	DBT	SØRT3 type output requests (XYPLØTTER, XYPRINTER, Random Request).
XYØUT	IC	Request to generate X-Y plots.

XYØUT$	M	Indicates restart with an X-Y plot request.
XYPEAK	IC	Request to print the maximum and minimum values of the specified response.
XYPLTCE	DBT	XY plot input data block, complex flutter.
XYPLØT	FMS	X-Y plot generator.
XYPLØT	IC	Request to generate X-Y plots.
XYPLTF	DBT	XYPLØT input data block. (D-8, D-11)
XYPLTFA	DBT	XYPLØT input data block. (D-8, D-11)
XYPLTR	DBT	XYPLØT input data block. (D-8, D-11)
XYPLTT	DBT	XYPLØT input data block. (D-9, D-12)
XYPLTTA	DBT	XYPLØT input data block. (D-9, D-12)
XYPRINT	IC	Request to tabulate XY pairs on the printer.
XYPRNPLT	FMX	Dummy output module.
XYPTTA	DBT	XY plot input data block, aeroresponse.
XYPUNCH	IC	Request to punch XY pairs.
XYTRAN	FMS	XY output translator.
XYZ	IC	Requests X, Y and Z vectors for deformed structure plot.
XZ	IC	Requests X and Z vectors for deformed structure plot.

Y	IC	Requests Y vector for deformed structure plot.
Y	M	Used in parameter section of DMAP statement. Indicates that parameter may be given an initial value with a PARAM bulk data card.
YAXIS	IC	Request for drawing of Y-axis.
YBDIVISIØNS	IC	Request for division marking on Y-axis of lower half frame.
YBGRID LINES	IC	Request for grid lines to be drawn on Y-axis of lower half frame.
YBINTERCEPT	IC	Specifies intercept of X-axis on Y-axis on lower half frame.
YBLØG	IC	Request for logarithmic scales in Y-direction on lower half frame.
YBMAX	IC	Do not plot points whose Y value lies above this value for lower half frame.
YBMIN	IC	Do not plot points whose Y value lies below this value for lower half frame.
YBS	DBM	Scalar multiple of YS matrix. Used in Differential Stiffness Rigid Format only. (D-4).
YBTITLE	IC	Y-axis title on lower half frame.
YBVALUE PRINT SKIP	IC	Request to suppress labeling tic marks over the specified interval.
YDIVISIØNS	IC	Request for division marking on Y-axis.
YES	IA	Option used on CHKPNT card, indicates that checkpoint is desired.
YGRID LINES	IC	Request for grid lines to be drawn on Y-axis.
YINTERCEPT	IC	Specifies intercept of X-axis on Y-axis.
YLØG	IC	Request for logarithmic scales in Y-direction.
YMAX	IC	Do not plot points whose Y value lies above this value.
YMIN	IC	Do not plot points whose Y value lies below this value.
YPAPER	IC	Specifies length of paper in Y-direction for table plotter.
YS	DBM	$\{Y_s\}$ - Constrained displacement vector.
YTDIVISIØNS	IC	Request for division marking on Y-axis for upper half frame.
YTGRID LINES	IC	Request for grid lines to be drawn on Y-axis for upper half frame.
YTINTERCEPT	IC	Specifies intercept of X-axis on Y-axis for upper half frame.
YTITLE	IC	Y-axis title.
YTLØG	IC	Request for logarithmic scales in Y-direction for upper half frame.

YTMAX	IC	Do not plot points whose Y value lies above this value for upper half frame.
YTMIN	IC	Do not plot points whose Y value lies below this value for upper half frame.
YTITLE	IC	Y-axis title for upper half frame.
YTVALUE PRINT SKIP	IC	Request to suppress labeling tic marks over the specified interval for upper half frame.
YVALUE PRINT SKIP	IC	Request to suppress labeling tic marks over the specified interval.
YZ	IC	Requests Y and Z vectors for deformed structure plot.
Z	IC	Requests for deformed structure plot.